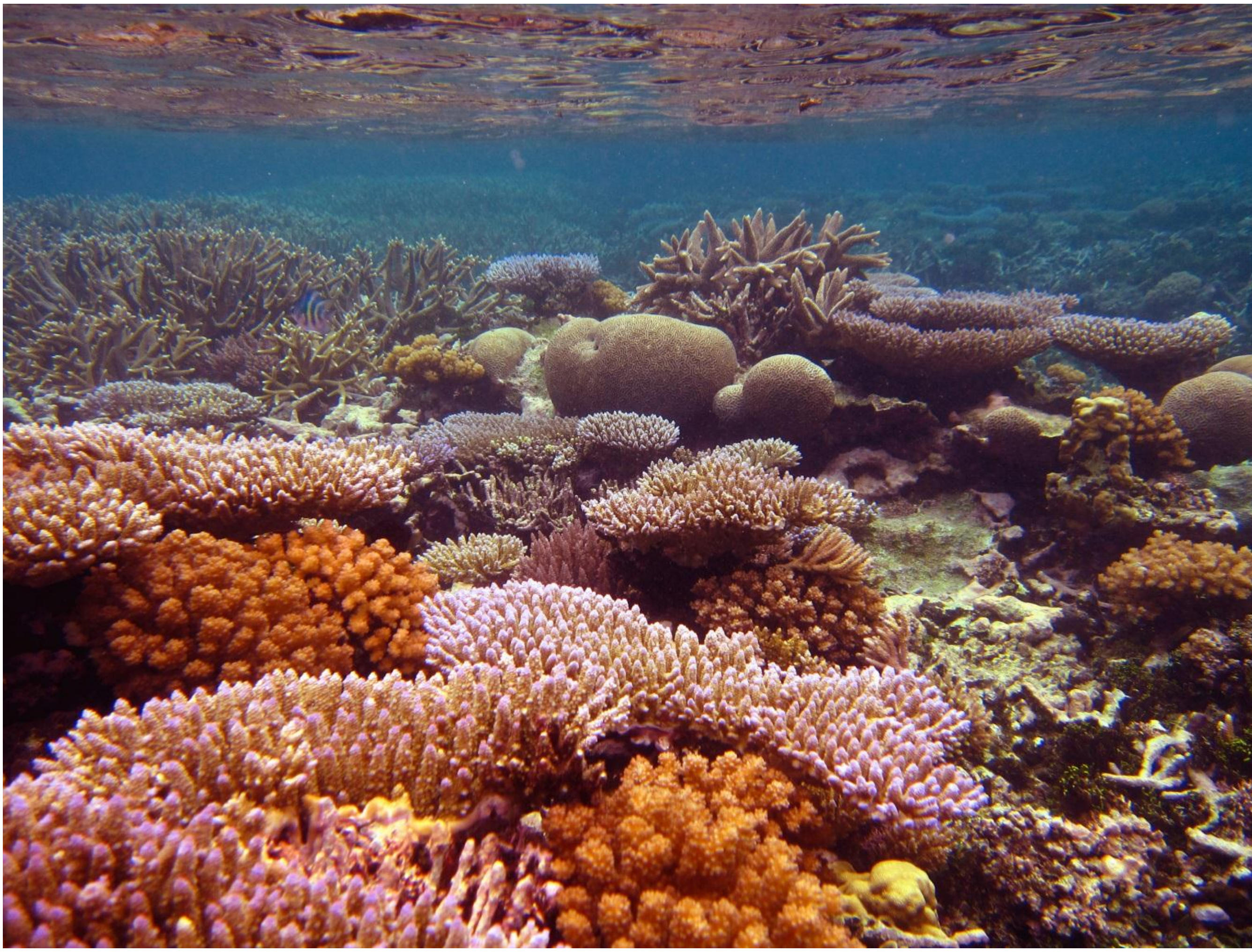

A Trainers Guide to *Reef Resilience and Climate Change Training Workshop*

Zanzibar, Tanzania
June 2013

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June 10-14, 2013

TABLE OF CONTENTS

Reef Resilience: Training of Trainers

Executive Summary

The Nature Conservancy, with support from the MacArthur Foundation and in collaboration with NOAA, is hosting the 2013 Training of Trainers Workshop, a comprehensive training workshop to build the capacity of managers to design and deliver their own Reef Resilience training programs.

The Reef Resilience and Climate Change workshop is designed for up to 25 participants and lasts 5 days. Trainees can use the materials and exercises in this training guide when designing future training activities. This is the fourth in a series of four workshops held in different parts of the world, including the Caribbean, Pacific, and Southeast Asia over the past four years. Each TOT has been unique and was flexible in order to meet the needs of each group of participants. Even so, these trainings have included 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, Communication and Evaluation skills. Facilitating a training course and working interactively with a group of trainees requires a thorough knowledge of presentation, facilitation, communication and evaluation skills.
3. Information about resources. Trainers need to be familiar with resources that can complement their knowledge and education, such as training guides, books on presentation skills and resources on content areas of training. The TOT workshop provides 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. The activities presented in this training guide 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 to ultimately advance the conservation strategies implemented in their geographies.

About this guide:
Each tab in the training guide is focused on a different topic and includes training activities and background information on the topic.

Acknowledgements

This workshop is funded through generous contributions from the John D. and Catherine T. MacArthur Foundation, the International Union for Conservation of Nature, 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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Facilitation

Navigating in Rough Seas: Planning and Facilitating Collaborative Meetings will be the main resource used in this workshop to guide the development of facilitation skills. This tab provides some background information on the importance of developing facilitation skills for reef managers and a brief overview of important considerations and tips for building facilitation skills. **See Navigating in Rough Seas booklet for full details on the facilitation materials presented during this training.**

Table of Contents

Facilitation: Background Information

Many coral reef managers and practitioners attend and lead meetings as part of their daily or weekly tasks. Most managers need good facilitation skills to be effective as they guide collaborative decision-making processes for resource management often and seek input from a variety of stakeholders. **The following background information is a brief overview of the concepts detailed in Navigating in Rough Seas.**

1. Planning and Executing Effective Meetings

A facilitator supports the meeting process by keeping the group on track to produce the desired objectives. Ideally, a facilitator is neutral toward the outcome of the meeting (NOAA 2010). The facilitator's job is to focus on effective processes (meeting dynamics), allowing the participants to focus on the content or the substance of their work together.

Coral reef managers often hold meetings or workshop to:

- Solve problems
- Identify shared priorities
- Develop or update management plans
- Create buy-in
- Make decisions
- Share information
- Plan work
- Learn from one another

A common misconception is that getting all the experts or stakeholders together in the same room will end in good results. As this is often not the case, most meetings or workshops benefit from facilitation. A well-facilitated meeting is both more efficient and effective.

How to plan effective meetings

The following steps can be followed to plan a productive meeting or workshop:

1. Define the meeting purpose and objectives: *Ask, why are we having this meeting?*
2. Create a participant list: *For a meeting to be truly successful, the right people need to participate!*
3. Establish roles: *Determine the roles people will play at the meeting*.
4. Develop the agenda: *The agenda provides the focusing framework for the meeting, puts tasks in a logical order and timeframe, and offers an outline for writing the summary at the meeting's conclusion*.
5. Identify background materials: *Provide the participants with the information needed to meaningfully participate in the meeting*.
6. Plan the meeting space: *An important part of meeting dynamics is the meeting environment!*

Meeting Tip:
When complete neutrality is needed, or when dealing with contentious issues, the group will benefit by using a facilitator from outside the organization or office. Using a professional facilitator is strongly encouraged when the meeting will have more than 40 participants.

For a meeting to be productive it is important for the facilitator to:
- Set clear expectations
- Manage time
- Lead effective collaborative group decision making
- Get participant feedback

Setting Expectations
Key steps to setting clear meeting expectations include identifying:
- Specific objectives to be achieved at the meeting
- Participant roles, both before and during the meeting
- Setting realistic expectations for the time available
- Communicating clearly with participants to prepare for the meeting

It is also important to explain how input will be gathered and used – before, during and after the meeting. For example, explain if there be a final report or another meeting or event. Participants should know if the decisions reached at the meeting will be final or if their input will be taken as a recommendation or for some other purpose.

Managing Time
Managing time effectively begins with assigned time limits to each topic or activity on the agenda. If you haven't done them before, it is very helpful to practice activities or presentations before the meeting (when possible) to test the time assumptions. Be sure to coach all presenters on their time allocations and stress the need to stay on time. Appointing a timekeeper with the authority to stop people, with warning, when their time is up along with having a visible clock in the room is helpful. When managing time, an experienced facilitator often finds it very useful to be flexible. Often during meetings, the facilitator must modify the agenda to achieve the ultimate goals of the meeting objectives. This includes determining what agenda items can be delayed or addressed in an alternate format (for example, by being delegated to a subgroup or participants, or to a single participant for further research or decision etc.). If the group discussion is going long and you are concerned about the agenda, a good tool is to review the key agenda items with the group and ask them how they want to use their remaining time. This often helps everyone get back on track.

Establishing Ground Rules
Establishing 'ground rules' is another key tool for effective meetings. Although most ground rules are common sense, it is useful to draw participant attention to them at the beginning of a meeting. This establishes the group agreement on how they want to work together and helps prevent problems. Examples of ground rules include: no cell phones (or put them on

silent/vibrate), returning on-time from breaks, everyone participates, no interrupting, showing respect for other participants, and focusing on the agenda item at hand. There are many other ground rules that can be used and it is often helpful for groups to decide on ground rules together before the beginning of a meeting.

Making Group Decisions

There are many methods available to aid groups in making decisions collaboratively. The most commonly used include brainstorming followed by clustering & voting; consensus decision making, consultation and prioritization. For information on determining the appropriate process to aid groups in collaborative decision-making, see references at the end of this tab.

Getting Participant Feedback

To make future meetings more productive, it is helpful to collect evaluation information from meeting participants. An evaluation form is a common way to get this feedback. There are many other options to consider, for example, a "Plus/Delta" method includes asking participants to make positive comments about the meeting (plusses) and comments on changes that could be made to improve meetings in the future (deltas).

2. Facilitation Techniques

The following techniques are used by facilitators during meetings to assist groups in accomplishing their objectives.

Facilitation Techniques Table taken from "Navigating in Rough Seas: An Introduction to Planning and Facilitating Effective Meetings," NOAA Coastal Services Center

Technique	**Description**
Breakout Groups	Some groups can be too large to enable in-depth discussion. For example, in a one-hour discussion session involving 100 people, many participants would not be able to share their thoughts. Depending on the nature of the issue, the facilitator may decide to break a large group into smaller groups of 5 to 20 participants. These groups usually "report" back to the larger group to share the results of their discussion or any decisions made.
Active Listening	The facilitator should look people in the eye, use attentive body language, and make participants understand that they are being heard. Body language should neither show support for or disapproval of any suggestions, comments, or ideas, since this can discourage open communication. The facilitator should face and take a step toward the person who is speaking to show interest.
Asking Questions	Questions test assumptions, invite participation, gather information, and probe for hidden points. The facilitator can ask open-ended questions to encourage thorough discussion of all ideas presented.
Paraphrasing	Paraphrasing involves repeating what has been said to let participants know they are being heard, to let others hear the point a second time, and to clarify key ideas. This also provides an opportunity to ascertain if the facilitator has correctly "heard" or interpreted what was said.

Summarizing	After listening attentively to all that has been said, a facilitator should offer a concise and timely summary. Summarizing is a good way to revive a discussion, or to end one when things seem to be wrapping up.
Synthesizing	While it may sometimes be appropriate to record individual ideas of each participant, in other situations the facilitator may encourage attendees to comment on and build on each other's ideas and then record the "collective idea" on a flip chart. This builds consensus and commitment.
Negative Polling	It is sometimes easier to reveal disagreement within a group than to confirm agreement. Often used during the "closing" part of a discussion, the negative poll is a way to find out if the group is ready to confirm a decision and move on to the next task. When using this tool, the facilitator can ask the group if anyone disagrees with what has been suggested or put forth by participants. If no one speaks up, it is usually safe to move on. If any individual has hesitation, he or she will usually speak up in a negative poll.
Boomeranging	Participants will often look to the facilitator to answer questions about content or suggest solutions. However, the facilitator is the process expert, not the content expert, and must resist the temptation to solve content problems for the group. Instead, the facilitator can "boomerang" the question back to the group by asking the following questions: • "*What do YOU think the groups should do?*" • "*What does the GROUP feel is the best choice?*" • "*How would YOU suggest solving this problem?*"
Restating the Purpose	When a discussion gets off track and participants are talking about issues that are not on the agenda, the facilitator can ask the group to pause and reconsider the meeting purpose or desired objectives. The facilitator may say, "*I sense this issue is important to the group, but the purpose of our meeting today is ______ ______ , so would it be okay to table this discussion until a later time?*"
3-Step Intervention to Deal with Disruptive Behaviors	The facilitator can use this intervention when a person's behavior is disruptive to the meeting. Step 1 – Describe problematic behaviors. For example, "Allen and Sue, both of you have left and returned three times during the meeting." Step 2 – Make an impact statement to tell group members how their actions are affecting the facilitator, the process, or other people. For example, "We had to stop our discussion and start over on three occasions because of this." Step 3 – Redirect the person's behavior. This can be done by asking members for their suggestions about what to do. For example, "What can we do to make sure this doesn't happen again?" or "Would everyone like a short break so that when we return everyone will be able to fully participate?"
Labeling Sidetracks	The facilitator should let the group know when it gets off track. The group can decide if it wants to pursue the sidetrack or get back to the agenda
Parking Lot	The facilitator can use a flip chart page, or ask the recorder to keep a sheet, labeled "Parking Lot." Sidetrack items are placed in the parking lot and reviewed later to determine if any should be included in a future agenda. Questions and concerns recorded in the parking lot need to be followed up—either by the facilitator or (more often) by the meeting leader.

Mirroring	The facilitator can periodically tell group members how they appear so they can interpret their actions and make corrections. This is particularly effective for drawing the entire group's attention back to the tasks at hand or dealing with disruptive behaviors. This is also a good way to see if the pace is too slow, too fast, or if the group needs a break. "*I see some confused faces out there. Do we need to clarify the process? Or perhaps take a break?"*
Remaining Neutral	The facilitator must focus on the "process" role and avoid the temptation to offer an opinion on the topic under discussion. A facilitator who becomes involved in the content discussion must let the group know that he or she is stepping out of the facilitator role.
Flip Chart Note Taking	Taking flip chart notes not only serves the purpose of recording decisions, priorities, and key points of discussion, but also focuses the group's attention and ensures that all participants are in agreement with what is being recorded. Some tips for utilizing flip chart notes effectively: 1. Ask participants to report whether their points are being captured accurately. 2. Write large enough for everyone in the room to be able to read; do not use flip chart notes in a large group where many participants would be unable to see the chart. 3. Consider using alternating marker colors for each main point to improve readability. 4. Label each page with the session it is from and a page number to make it easier to type up the notes later.

Tips for Videoconference and Webinars

Due to the remote locations of many coral reefs areas, it is increasingly common for managers to utilize conference calls, videoconferences and webinars. Tips for facilitating meetings where one or all group members are participating via video, phone or online include:

Before the meeting:

- Be sure that all participants have directions for how to access the meeting, including call-in codes, directions for joining the webinar etc.
- Make special arrangements for delivery of all meeting materials in advance.

During the meeting:

- Conduct a roll call so participants are aware of others and participation is encouraged.
- Set ground rules.
- Note participation so that quieter participants can be asked to join the discussion.

Meeting Tip:

Ask participants to mute their phones when not speaking to minimize noise during the webinar or meeting.

3. Ice Breakers/Energizers and Closing Ceremonies

Facilitators use games for a variety of different reasons, including helping people to get to know each other, increasing energy or enthusiasm levels, encouraging team building or making people think about a specific issue. Games that help people to get to know each other and to relax are called **ice breakers**. When people look sleepy or tired, **energizers** can be used to get people moving and to give them more enthusiasm. Other games can be used to help people think through issues and can help to address problems that people may encounter when they are working together. Games can also help people to think creatively.

Ice Breakers:

These can be an effective way of starting a training session or team-building event. As interactive and often fun sessions run before the main proceedings, they help people get to know each other and buy into the purpose of the event. If an ice breaker session is well-designed and well-facilitated, it can really help get things off to a great start. By getting to know each other, getting to know the facilitators and learning about the objectives of the event, people can become more engaged in the proceedings and so contribute more effectively towards a successful outcome.

Examples of Ice Breakers:

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 get 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 fiction, 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:

There are many reasons to use energizers in the middle of a meeting. You might use very brief ones to segue between agenda items, or longer ones to help everyone drop one topic of discussion and move on to the next. Energizers can also help everyone re-focus after a coffee break or lunch. Examples include:

Animal Line-up (Also known as: Noah's line-up, Ark Arrangement)

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.

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:

Closing exercises provide a way for the group to synthesize the discussions, ideas, and action developed during the workshop, and sometimes can set next steps for action.

Examples of Closing Exercises:

The big hug – Ask the group to form a large circle. Read of a list of statements. If the statement is true, then the participant should step forward. Read statements that gets people to step forward - I liked the workshop, I learned something new today, I have ideas for next steps I can use in my community, I'm hungry. Continue to step forward until people are standing very close to each other. Have a group hug or other way of expressing thanks to the group. The big hug activity shows appreciation to the experience shared in the workshop.

One word – can also be used during closing. Ask people to stand in a circle. Ask participants to answer a question with a one word answer – What gives you hope? What do you appreciate about their neighbor? People can go around in a circle or answer spontaneously. This is a short, and fun way to end a meeting. Remember to keep it positive!

Head, heart, feet – Hang up a drawing of a person. Ask participants to think about three questions about the workshop – What did you learn? How did you feel? What are you going to do? Ask them to write down one answer and then tape it near the head, the heart, or the feet in the drawing (or have them say their answers out loud). This activity is a way to evaluate participant's thoughts and feelings.

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.

4. Evaluating Training Effectiveness

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.

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 that 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.

The following evaluation templates can be modified to become specific for your training:
Evaluating Reef Resilience Knowledge (on flash drive)
Evaluating Training Effectiveness (on flash drive)

Principles of Reef Resilience

This tab focuses on introducing the principles of reef resilience in the TNC Resilience Model. This information is the basis for all other training activities. To help trainees understand how this information may change their approach to management strategies, there is a group activity that can be useful to conduct.

Table of Contents

Principles of Reef Resilience: Training Guidance

Estimated Time
15 minutes – Principles of Reef Resilience Activity Part 1
45 minutes – Powerpoint Presentation
15 minutes – Principles of Reef Resilience Activity Part 2
10 minutes – Group Report Back

Seating Arrangement/Group Size
Group Activity – 5 students per group max with facilitator
Full Session – Up to 25 students (absolute max is 30)

Learning Objectives
By the end of this training students will be able to:
- ✓ Define biological and social resilience
- ✓ Explain the three components of social resilience
- ✓ Identify and explain the four main principles of reef resilience from the TNC model
- ✓ Identify the three major factors of resilience and explain the resilience bottlenecks
- ✓ Explain the genetic and species differences that influence coral stress response
- ✓ Describe physical conditions that may increase resistance to temperature stress
- ✓ Describe effective management fundamentals: communication, measuring up, adaptive management, and precautionary approach

Activity Description
1. Conduct Activity Part 1 (15 minutes)

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

Instructions:
- Divide into small groups of 4-5 participants
- Give the participants the following instructions: Using the map provided (see Powerpoint), draw MPA boundaries using the following list of assumptions/criteria on the map (Feel free to have zones for different uses).

<u>**Criteria**</u>	<u>**Assumptions**</u>
tourism	minimal threats
fisheries	fisheries OK
biodiversity	no communities

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

2. Give Powerpoint Presentation: Principles of Reef Resilience (45 minutes)

3. Conduct Activity Part 2 (15 minutes)
   Instructions:
   - Review original MPA design, change if necessary to incorporate resilience based on the model just presented.
   - Discuss and list what changed between their first and second attempt to design an MPA

4. OPTIONAL: Group Report Back (10 minutes)
   - Have one person from each group report back to the larger group what changed between their first and second attempt to design an MPA. (Note: the large group report out can be optional depending on time)

Notes to the Instructor/Additional Resources

Concept Emphasis:

- If managers do nothing more than strengthen their current management strategies, they will be making great strides toward resilient systems
- If managers can, work to reduce the take of these species. They are CRITICAL to reef health.
- 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.
- 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?
- 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).
- 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.
- 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).
- 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.

Materials Needed

- Powerpoint Presentation: Principles of Reef Resilience (Flash drive)
- One flip chart page per group with pre-drawn map (see MPA Design handout on Flash drive)
- Multi-colored markers – 1 pack per group

Principles of Reef Resilience: Background Information

Coral reefs are among the oldest ecosystems on earth, and are not only hotspots for biodiversity, but also provide countless services and economic benefits to local communities.

Unfortunately, coral reefs worldwide are in crisis. In the last few decades, global-scale stressors related to climate change are increasingly recognized as a significant threat to coral reef ecosystems. The combination of global-scale stressors with local stressors has resulted in declines in reef communities worldwide.

Managers can take actions to support coral reef resilience, to conserve these valuable ecosystems for future generations. Coral reef ecosystems that are more resilient to the impacts of global and local threats are better able to resist and recover from such impacts, and are therefore more likely to survive into the future. For example, a resilient reef may suffer coral mortality during a bleaching or storm event, but will maintain key ecosystem structure and function.

1. What is Resilience?

Resilience is defined as the ability of a system to maintain key functions and processes in the face of stresses or pressures by either resisting to or adapting to change (Holling 1973; Nystrom and Folke 2001). Resilience consists of two components: resistance, which is the ability to absorb or resist impacts, and recovery, the ability to recover from them.

Resilience can be applied to all marine ecosystems in temperate, tropical and polar regions and can also be applied to social systems (e.g., human communities). In this training, resilience is specifically applied to coral reef ecosystems. Reef resilience refers to building resistance and recovery potential into coral reef ecosystems by reducing the impacts of stressors (e.g., overfishing, pollution, coastal development, etc.).

Ecological Resilience

Ecological resilience refers to the ability of an ecosystem to maintain key functions and processes in the face of stresses or pressures, either by resisting or adapting to change (Holling 1973; Nyström and Folke 2001). Resilient systems are characterized as adaptable, flexible, and able to deal with change and uncertainty (Hughes et al. 2005).

Building resilience into an ecosystem means working to support the health and function of associated habitats, organisms, and ecosystem processes. The ecological processes that maintain reef function and support thriving reef communities play an important role in maintaining resilience to major disturbances. Complex food-web interactions (e.g., herbivory, trophic cascades), reproductive cycles, population connectivity, and recruitment are key ecological processes that support the resilience of ecosystems like coral reefs.

Social Resilience
Social resilience is defined as the ability of a community to cope with adapt to stresses such as social, political, environmental or economic change (Adger et al. 2000). It shares much with the concept of ecological resilience, but with an important difference: humans have the ability to anticipate and prepare for future conditions (Cinner et al. 2011). For managers, this means that there is scope to work with reef-dependent communities to understand their vulnerability to changes in reef condition and support adaptation efforts. Healthy and prosperous people have more options available to them and thus are more capably of ensuring their activities are supporting, rather than eroding, ecosystem resilience. Management programs that value sustainability of coastal communities are also more likely to benefit from stronger community support, reduced transaction costs and increased compliance. In short, coral reef managers that invest also in supporting ecosystem-based adaptation (the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change) in coastal communities are more likely to achieve their long-term conservation goals.

2. Identifying Reef Resilience Factors

Coral Reef Resilience

Although ecological resilience was defined previously (Holling 1973) for ecosystems that can shift towards alternative states (e.g., from a coral to algal dominated state), here we are using a more general definition of resilience that emphasizes processes that support coral populations. In the context of this training, coral reef resilience relates to a reef ecosystem's ability to recover from a disturbance and recover towards a coral-rich state, and/or to maintain morphological diversity as opposed to shifting to an algal-dominated state or a single coral morphology (Marshall and Schuttenberg 2006).

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 strengthening this immune system and increasing the likelihood that coral communities will continue to thrive.

What does resilience look like for coral reef ecosystems?
As a coral reef manager, it is helpful to have a good sense of what resilience looks like for a coral reef. Resilience is more than resisting or being able to recover from a major disturbance, such as 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.

Some indicators of a healthy and resilient coral reef include:

- Strong coral recruitment— Indicates strong connectivity to healthy source reefs (although the reef may be self-seeding) and good conditions for larval settlement and growth (available substrate, good water quality)

- Broad coral size/age range— Indicates that corals have survived previous stress events regularly to reproduce, settle damaged areas, and recover, and that conditions favor recovery. For instance, large, old corals may indicate a long history of surviving or avoiding stress and the intermediate sizes and small young ones indicate maintained health of the system, including regular reproduction and regular strong larval settlement and growth
- Low human impacts— Indicates a lower level of local stressors that weaken the 'immune system' of coral reefs; low human impacts may mean corals will be able to resist and recover from major stress events more effectively
- High biodiversity— Indicates that resilience may be enhanced as biodiversity helps ensure that enough redundancy of functional groups exists. For example, corals form an important functional group that provide three-dimensional habitats for fishes and other organisms and contributes to reef growth. Herbivores constitute another functional group that plays a key role in controlling algal growth, thereby helping to enhance coral recruitment, reef recovery, and resilience (Steneck and Dethier 1994) to maintain ecological processes and to protect against environmental disturbance (McLeod et al. 2009).
- Healthy herbivore populations— Indicates a high potential for coral reefs to recover from major stress events as herbivores graze down algae and thus prepare the substrate for larval settlement, which supports coral reef recovery following disturbance
- Healthy corals (low levels of disease)— May indicate good water quality, low levels of stress, and strong metabolism, although healthy corals may also mean that a community simply has not yet experienced stress (e.g., cyclone or disease). High coral cover can contribute to resilience (e.g., by supporting increased herbivory), but it is important to ensure that processes are also in place that support resistance and/or recovery from stress)
- History of surviving stress— Indicates the presence of oceanographic or other factors that help corals avoid, tolerate, or resist stress, such as a former bleaching event

High coral cover has also often been cited as an indicator of resilience for coral reefs. However, it is important to note that high coral cover of a highly susceptible species to large-scale stresses such as a bleaching event or disease outbreak (e.g., *Acropora)* does not indicate resilience. A diverse coral community with multiple species is likely to be more resilient than a community made up of only one highly susceptible coral species. A diverse coral community with multiple species is likely to be more resilient than a community made up of only one highly susceptible coral species.

Multiple factors contribute to resilient coral communities, some of them well known and others to be discovered. Scientists are working to identify important ecological, biological, and physical factors that managers can evaluate to assess the resilience of a coral community. Additionally, recent research highlights fundamental differences in the recovery and state of Caribbean versus Indo-Pacific reefs, and identifies a number of factors that might predispose the Caribbean to lower resilience (Roff and Mumby 2012).

Resilient systems are characterized as adaptable, flexible, and able to deal with change and uncertainty (Hughes et al. 2005). Coral reef resilience relates to a reef ecosystem's ability to resist disturbance and recover towards a coral-rich state. It includes maintaining morphological diversity and resisting a phase shift (change in reef community structure such as shifting from a coral to an algal-dominated state).

Corals tolerate relatively narrow ranges of temperature, salinity, water clarity, and other chemical characteristics. Coral reefs are most diverse and abundant in regions that have extremely little annual change in their physical environment (e.g., the Coral Triangle has the lowest thermal variation in the tropics); regions with greater thermal change in a year have fewer species. Therefore, any factor that changes a coral's physical environment can cause stress such as bleaching. But there are multiple favorable factors that may help reduce stress or help corals to cope with it.

The resilience of a reef is influenced by ecological, biological, chemical, and physical factors. These factors affect how a reef copes or change with stress and can be used to inform management strategies that support resilience. For example, if managers can identify specific locations with factors that enhance resistance to and/or recovery from a stress event, or areas where factors are present that either reduce the intensity of stress or help corals to avoid it altogether, then these areas can be priorities for protection.

Ecological, biological, chemical, and physical factors can influence how much stress corals experience and also how corals respond to stress (e.g., bleaching, disease). These factors can be either internal (e.g., heat-tolerant zooxanthellae, genetic make-up of the corals) or external (e.g., oceanographic conditions that cause mixing which can cool surface water and reduce heat-stress, naturally occurring suspended or dissolved matter that reduces sunlight penetration in the water column and reduces radiation stress.

2.1. Ecological Factors

Ecological processes that maintain reef function and support thriving reef communities play an important role in maintaining coral reef resilience. This section explores two ecological processes, herbivory and recruitment, which are critical for coral recovery following disturbance events, and therefore are necessary for maintaining resilience.

Herbivory

Macroalgae can inhibit resilience by overgrowing and killing coral colonies, and by producing toxic chemicals which can kill corals or limit coral recruitment by lowering coral fecundity (the capacity of an individual or population to reproduce), settlement rates, and post settlement survival. Herbivores help keep the substrate free from algae so that coral recruits can settle. When herbivores are not present, faster growing macroalgae can overgrow corals. This deprives corals of essential sunlight which can cause declines in coral condition and cover and also reduces the space available for coral settlement. This can result in a phase shift [a significant change in community structure and composition (shift to an alternative state)] from a coral-dominated system to an 'algal-dominated system' (Green and Bellwood 2009).

Herbivores are diverse and do not constitute an ecologically uniform group. They include several groups that differ in terms of how they feed, what they eat, and their impact on the substrate. There are four functional groups (a collection of species that perform a similar function, regardless of their taxonomic group) of coral reef herbivores—scrapers, grazers, browsers and excavators—and each has a role in maintaining healthy reef systems (Green and Bellwood 2009).

Herbivores help to regulate community structure and function in many ecological systems. In addition to regulating and influencing the competitive interactions between corals and macroalgae, herbivorous fishes and urchins are also agents of bioerosion (the breakdown of calcareous material from the reef by biological process). For example, parrotfishes excavate the surface of the reef matrix or living coral as they feed, and the material is processed by their jaws, reduced to sediment and expelled back into the system. Such processes on coral reefs play an important role in maintaining the balance of reef growth and decay. Bioerosion contributes to reef recovery by removing dead coral and cleaning areas of substratum for colonization by benthic organisms, facilitating the settlement, growth and survival of coralline algae and corals.

Feedback mechanisms on coral reefs

Ecological feedback mechanisms on coral reefs may have either positive or negative trajectories, and these are controlled primarily by the amount of grazing intensity (i.e., is the grazing intensity high enough to control overgrowth of macroalgae). Disturbances such as overfishing of herbivores, coral bleaching, and coral disease may contribute to the decline of corals or overgrowth of macroalgae. Once a reef is dominated by macroalgae, negative feedbacks reinforce the dominance of macroalgae making it hard for corals to recover (Mumby and Steneck 2008; Rasher and Hay 2010).

An example of a negative feedback is insufficient grazing intensity. This could be caused by reduced herbivorous fish biomass (e.g., due to overfishing), high algal productivity (e.g., due to elevated nutrient concentration) and/or low coral cover (recent bleaching event). Once macroalgal growth outpaces the ability of reef herbivores to control macroalgal biomass, macroalgae blooms and reef degradation can be quick and difficult to reverse because macroalgae can damage corals and reduce coral settlement. A decline in corals reduces the structural complexity of the reef; lower habitat complexity can reduce coral recruitment (reduced availability of refugia from algae), and herbivorous fish recruitment (due to increased predator efficiency; Mumby and Steneck 2008). Researchers have documented coral decline in response to removing herbivorous fish from a reef at both local and regional scales (Jackson et al. 2001; Steneck et al. 2001; Hoegh-Guldberg et al. 2007; Hughes et al. 2007; Burkepile and Hay 2008; Mumby and Steneck 2008; Rasher and Hay 2010).

In an experimental manipulation of large herbivorous fishes, Hughes et al. (2007) tested the influence of herbivores on the resilience of coral assemblages. The experiment was undertaken on the Great Barrier Reef after the regional-scale bleaching in 1998 within a no-fishing reserve where coral abundance and diversity had been sharply reduced by bleaching. In control areas, where fishes were abundant, algal abundance remained low, whereas coral cover almost doubled (to 20%) over a three year period, primarily because of recruitment of species that had been locally extirpated by bleaching. In contrast, exclusion of large herbivorous fishes caused a dramatic explosion of macroalgae, which suppressed the fecundity (the capacity of an individual or population to reproduce), recruitment, and survival of corals. Consequently, management of fish stocks is a key component in preventing phase shifts and managing for reef resilience.

Recruitment

Recruitment is the process by which young individuals (e.g., fish and coral larvae, algae propagules) undergo larval settlement and become part of the adult population. The rate, scale, and spatial structure of larval dispersal drive population replenishment, and therefore have significant implications for population dynamics, marine reserve orientation, and resilience of a system.

Fundamental steps required for successful recruitment include: 1) the availability of competent larvae (dependent on connectivity); 2) the ability of larvae to settle—often aided by chemical cues that induce settlement and metamorphosis; and 3) the availability of suitable settlement substrate where post-settlement survival is high (Arnold et al. 2010).

Settlement and recruitment of coral larvae occurs only if certain conditions are met, and the behavior of coral larvae controls their ability to settle. For example, for coral larvae to settle, the larvae must move to specific depths, seeking specific light intensities that favor settlement. Once the larvae contact the benthos (i.e., seafloor), some organisms such as coralline algae provide chemical cues that trigger coral metamorphosis and settlement (Arnold et al. 2010).

Guidance for Managers

Exploring the following questions pertaining to recruitment can provide managers with a better understanding of recruitment at their sites and can inform management strategies, such as placement of MPAs, fishing restrictions or watershed management.

A. What physical oceanographic conditions characterize the site?

Large-scale physical oceanographic processes, such as ocean currents, upwelling, and eddies can cause considerable mixing and affect long-distance transport of pelagic (of or relating to open ocean) larvae. These large-scale processes also affect recruitment patterns at smaller scales (site-level); currents and areas of upwelling will have a direct effect on the extent of larval transport to distant locations and the movement of larvae over particular sites, and thus overall patterns of recruitment. At a smaller scale, other physical processes can either enhance or inhibit larval dispersal and recruitment patterns such as micro-currents, small eddies, light, areas of flow constriction, salinity, depth, and sedimentation.

- To better understand large-scale oceanographic processes and how they affect local areas, managers can examine oceanographic currents within the area. Information on surface ocean currents and tides provide managers with the general movement patterns and expected larval distribution.

- With recruitment pattern information, managers can make informed decisions about MPA sizes, locations and distances between MPAs within a network. However, analyzing physical oceanographic conditions and modeling larval transport and dispersal patterns to inform MPA design is a relatively new field and can be very challenging (Cowen et al. 2006; Steneck et al. 2009). It is likely to require significant technical expertise, access to complex models, and partnerships between oceanographers and managers.

B. Where are the sources of larvae for the site?

The production, settlement, and survival of larvae depend upon the availability of source areas, a habitat patch capable of supporting stable or growing populations and is a net exporter of individuals (Crowder et al. 2000). The source of larvae can be an external location, or the source can be local if larval production and settlement occur on the same reef. If the source is local, the system is considered self-recruiting and is not dependent on outside sources of larvae for replenishment. The pattern of larval exchange, and the degree to which larvae originate from outside populations, helps to explain connectivity between and among coral reefs. A large amount of self-seeding leads to low connectivity, while high rates of larval exchange with other populations generate high connectivity (Levin 2006).

Understanding coral recruitment patterns such as where larvae originate and settle is a challenge. In the field of larval ecology, scientists used to consider that larvae were passive particles carried by ocean currents to locations far from their birth site. However, studies suggest that some reef fish populations are actually self-recruiting, and larvae and juveniles are able to intentionally return to their birth sites (Jones et al. 1999; Swearer et al. 1999). The authors found higher than expected (possibly as high as 60%) self-recruitment in reef fish populations, and more recent studies (Jones et al. 2005; Almany et al. 2007) support these original findings. Scientists are finding that most corals recruit relatively locally (Sammarco and Andrews 1989; Hughes et al. 2000; Shanks et al. 2003) because corals have relatively short larval durations (days to weeks), and many corals actually recruit closer to their source than reef fish (Steneck et al. 2009). Studies demonstrating local retention of larvae are important because they suggest that marine reserves can provide recruitment benefits not only beyond, but within their boundaries.

Most reef ecosystems are not exclusively self-recruiting or dependent on outside sources. Proportions of larvae originating from internal or external locations can vary widely within and between reef systems. If an exclusively self-recruiting coral community suffers mass mortality from a disturbance event, there is little prospect for recovery, since all of the sources of larvae were impacted. Likewise, recovery of a coral community that depends solely on external sources is completely dependent on the arrival of coral larvae that have survived the disturbance event. A reef that both provides and receives larvae is more likely to be resilient to disturbance for two reasons because: 1) it has multiple sources of larvae to enhance recovery and 2) access to external larvae may increase the potential for greater genetic diversity.

- To support recovery from disturbance (e.g. bleaching), it may be optimal to have a combination of both self-recruitment and external sources of recruitment.
- Recording of recruits should be included in site monitoring protocols to help determine a reef's recovery potential.
- Management actions should be prioritized that reduce algal biomass on coral reefs because algal overgrowth reduces the survival of newly settled corals.
- Management actions that reduce algal biomass caused by overfishing of herbivores or eutrophication (e.g., establishing no-take areas, improving water quality) will help improve coral recruitment and consequently, coral recovery following a disturbance.
- Herbivores should be managed at the scale of the entire reef because herbivores play such an important role in coral reef ecosystems. Examples of such management strategies include policies that outlaw the take of herbivorous fishes across entire countries (e.g., Bonaire, Belize) and policies that outlaw the export of reef fish (e.g., in Palau).

C. Is there suitable habitat for recruits?

Finding unoccupied space and suitable habitat for settlement on coral reefs is a competitive process for coral larvae. If a habitat is unfavorable to settling corals, then recruitment will not be successful.

Larval behavior (controlling movement, metamorphosis, and settlement), environmental conditions (e.g., ocean currents that affect larval transport), and availability and type of substrate (e.g., presence of coralline algae and/or absence of macroalgae) all influence the ability of larvae to settle. Substrate type is an important factor influencing coral larvae settlement and a possible determinant of coral community structure. Substrates, such as live coral, sediment, macroalgae, encrusting sponges, and loose, unconsolidated substrate are unsuitable for coral recruit settlement. Suitable recruitment habitat includes a stable bottom type, limited sedimentation in water column, and absence of large macroalgae.

The suitability of a surface for coral settlement is determined by chemical or biological properties of the surface. The presence of algae can greatly reduce survivorship and settlement success of coral planulae (the free-swimming larval form of coral). A recent study of the common Hawaiian reef-building coral *Montipora capitata* found a negative relationship between density of early life history corals (1-3 polyps) and fleshy coral algal cover. Planulae that settle in algal dominated areas not only suffer from increased indirect, algal-induced mortality, but also experience lower recruitment success as algae are unlikely to serve as stable substratum for future colony growth (Vermeij et al. 2009).

The presence of chemical properties in crustose coralline algae (CCA) and other substrates, such as dead coral, have been shown to encourage coral larvae settlement (Norstrom et al. 2007). Coral larvae appear to be able to recognize and respond to chemical signatures in CCA in the selection of settlement habitat location (Harrington et al. 2004).

Monitoring programs should evaluate the availability of suitable habitat, looking specifically for areas of CCA or patches of dead coral which may provide adequate settlement substrate for new coral recruits. Managers can use this information to ensure that areas with an adequate supply of recruits and suitable substrate habitat are included in protected areas.

D. What is the herbivorous fish assemblage at the site?
Herbivores play a key role in influencing competitive interactions between corals and macroalgae (i.e., herbivores consume algae and create space for coral recruits to settle). Therefore, the abundance and community structure of herbivorous fish and invertebrate grazers can greatly influence coral recruitment. The presence of grazing reef fish, such as parrotfish, can reduce macroalgal cover and thus facilitate coral recruitment (Mumby et al 2007).

- Management that is designed to enhance coral recruitment should include strategies that reduce algae cover through the maintenance of high levels of grazing reef fish and invertebrates. To do this, managers need to evaluate the types and extent of grazing occurring within the area.
- Prohibiting or limiting the take of herbivorous species is critical for maintaining reef resilience in areas where herbivores are targeted, and should be a high priority for reef management in algal-dominated systems.

2.2. Biological Factors

This section provides information about biological characteristics that affect whether or not a coral bleaches during a warm water event. Individual corals vary in their responses to light and heat stress. Such differences in sensitivity in corals and zooxanthellae are affected by biological characteristics such as:

- Species Differences
- Genetic Differences
- Other Factors Affecting Bleaching Susceptibility (e.g., fluorescent tissue proteins, heat-shock proteins, colony integration, changes in feeding behavior in response to thermal stress, and tissue thickness)

Not all coral species are equally susceptible to bleaching. In response to elevated sea temperatures, some corals may bleach, while other coral species in the same location may not. Some corals are able to acclimatize to local temperature increases over time.

In general, coral species that are more resistant to bleaching can be characterized by massive growth forms, thick or less-integrated tissues and slow growth rates. Examples of coral genera recognized as more resistant to thermal stress include:

Acanthastrea	*Leptoria*
Cyphastrea	*Merulina*
Diploastrea	*Montastrea*
Favia	*Platygyra*
Galaxea	*Porites*
Goniastrea	*Turbinaria*
Hydnophora	

At the coral colony level, fast-growing species that are characterized by fine-structured, branching or tabular growth forms tend to be more susceptible to bleaching. These more susceptible coral genera include: *Acropora*, *Millepora*, *Montipora*, *Seriatopora* and *Stylophora.*

It is important to note that no species are completely immune from bleaching-induced mortality and nearly all genera have suffered high mortality during severe bleaching events in one location or another (Baker et al. 2008).

Zooxanthellae Genetics

The term "zooxanthellae" refers to a wide variety of algae of the genus *Symbiodinium*. *Symbiodinium* is a genetically diverse group of unicellular algae, including nine phylogenetic types, distinguished as clades A-I. These genetically distinct clades have different environmental, ecological and geographic characteristics which influence the resistance and resilience of corals to thermal stress. Studies have revealed that the different clades of zooxanthellae have different susceptibilities to thermal and light stress.

Clade D *Symbiodinium*

Clade D *Symbiodinium* are thermally tolerant and increase the resistance of corals that harbor them to elevated SSTs (Berkelmans and van Oppen 2006; van Oppen et al. 2009; Rowan 2004; Baker et al. 2004). Clade D *Symbiodinium* are found in a diverse range of coral species that encompass a variety of characteristics. Clade D *Symbiodinium* are present in higher abundance on some reefs than others, and these are often reefs exposed to relatively high levels of thermal stress or local stressors such as sedimentation or reefs with a history of coral bleaching. For example, clade D *Symbiodinium* is more abundant in acroporid corals from back-reef lagoons in American Samoa, where the SSTs reach higher maximum temperatures than the fore-reef environments, where *Acropora* primarily hosts clade C (Oliver and Palumbi 2009 and 2010).

Because they are often found in increased abundance on reefs that are exposed to environmental stressors, the presence of clade D symbionts can be a biological indicator of negative changes in coral health, but not always: they can also indicate positive acclimatization to stressful conditions. Information on abundance of clade D zooxanthellae can help managers understand the susceptibility of specific corals to thermal stress and also to identify changes in coral reef health.

Coral Fitness Trade-offs of Clade D *Symbiodinium*

Hosting a more heat-tolerant *Symbiodinium* will be accompanied by tradeoffs in the physiology of the coral. More heat-resistant zooxanthellae may come with ecological costs, such as reduced growth and reduced reproductive ability, and hence lower recovery following damage. A study conducted in the islands in the Keppel region of the Great Barrier Reef investigated skeletal growth. Under controlled conditions, *Acropora millepora* corals with clade D symbionts grew 29% slower than those with clade C2 symbionts. In the field, clade D colonies grew 38% slower than clade C2 colonies. These results demonstrate the magnitude of trade-offs likely to be experienced by this species as they acclimatize to warmer conditions by changing to more thermally tolerant clade D zooxanthellae.

Zooxanthellae Mechanisms

The ability to associate with multiple zooxanthellae clades is common in corals (Silverstein et al. 2012). The selective exchange of zooxanthellae is a potential mechanism by which corals might survive climate stressors, such as increased sea temperatures. Changes in the dominant zooxanthellae types of a coral colony may occur through two processes:

- shuffling — changes in the relative abundance of zooxanthellae clades that are already present in the coral tissue
- switching — uptake of new zooxanthellae clades from the environment

Acclimatization versus adaptation

The terms acclimatization and adaptation are often used synonymously but are not the same. Acclimatization refers to physiological changes whereas adaptation refers to genetic changes.

Acclimatization

- Changes occurring within the lifetime of an individual organism
- Changes that result from chronic exposure to an environmental change and help an individual survive in a given environment. Such changes cannot be transmitted to offspring

Adaptation

- Changes occurring over generations within a species
- Changes that provide an enhanced ability to survive and reproduce in a particular environment

In the short term, corals with flexible symbioses may shuffle or switch zooxanthellae; and an increase in the abundance of thermally tolerant zooxanthellae strains (such as those of clade D) is expected with an increasing frequency of bleaching conditions. The potential to adapt to increasing sea-surface temperatures depends on the extent of genetic variation for heat tolerance, the generation time of the coral host and zooxanthellae and the strength of selection.

Other Factors Affecting Bleaching Susceptibility

Knowledge of biological characteristics of individual corals enhances the ability to predict stress responses to a warm water event.

Several biological characteristics of corals may contribute to their ability to resist bleaching, including:

- **Heat-shock proteins.** Many different heat-shock proteins are found in coral tissues and their activity influences the bleaching response. Heat-shock proteins help maintain protein structure and cell function, following stress (Baird et al. 2009). For example, high-light-acclimatized tissues of the coral *Goniastrea aspera* have higher concentrations of heat shock proteins and these tissues do not bleach, unlike areas of the same colony that had not acclimatized to high light (Brown et al. 2002).

- **Fluorescent tissue proteins.** Corals are known for their bright colors, due primarily to fluorescent proteins in their tissues. Fluorescent proteins provide a system for regulating light; they protect the coral from broad-spectrum solar radiation by filtering out damaging UVA rays. The protective capacity of these proteins provides an internal defense mechanism that may have important implications for long-term survival of corals exposed to thermal stress. Corals containing fluorescent capacity have been found to bleach significantly less than non-fluorescent colonies of the same species. Furthermore, a recent study (Palmer et al. 2009) identified an additional role of fluorescent proteins as antioxidants, which may help to prevent stress in coral. Concentrations of fluorescent proteins vary among species (e.g., pocilloporids and acroporids have relatively low densities, while poritids*,* faviids and other slow-growing massive corals have high densities).

- **Change in feeding behavior in response to thermal stress.** Some corals rely heavily on food particles captured from the water column to supplement their energy requirements. These corals may be less dependent on the energy provided by their zooxanthellae, and thus less prone to starvation during a bleaching event when zooxanthellae are expelled from the coral. Additionally, some corals are able to change their feeding behavior in response to bleaching. Evidence suggests that coral species which can change their feeding behavior may survive bleaching better than species which cannot (Baird et al. 2009).

- **Tissue thickness.** The thickness of coral tissues may contribute to the level of susceptibility to bleaching. Thin tissue is found in coral species that are more susceptible to bleaching. Thicker tissue may help shade zooxanthellae from intense light, reducing thermal stress, and thus decreasing the chance of bleaching.

Guidance for Managers

Guidelines for identifying stress tolerant corals include the following (Marshall and Schuttenberg 2006; West and Salm 2003):

- Compile existing data or local knowledge of composition of coral communities at sites. Identify dominant coral groups and rank their bleaching tolerance based on morphology (massive>encrusting>branching/tabular)
- Conduct surveys of coral community composition at sites and assess dominance of coral types known to be more resistant or tolerant to bleaching.
- If data are available, use physiological studies of dominant corals to assess likely resistance and tolerance based on zooxanthellae type, photo-protective pigments, or tissue condition (lipid levels), and/or heterotrophic capacity.
- Healthy corals in areas that historically have been exposed to high sea temperatures and areas that experience thermal variability may be more resistant to bleaching, thus these areas may also be priorities for protection.
- Once managers have assessed the stress tolerance of corals at sites based on the actions listed in the previous bullets, they can use this information to inform MPA design and management. For example, areas that are dominated by stress tolerant corals may be

considered priorities for protection in MPAs. Areas dominated by highly susceptible species will be critical to monitor following thermal stress events to assess the ecological responses of the corals to bleaching.

A broad spatial resilience approach is recommended for MPA network site selections. Sites within the network should include corals that exhibit a range of resistance properties. Sites that contain corals exhibiting resistance properties serve as refuges and sources of seed, and may be vital to connectivity.

2.3. Physical Factors

Any factor that changes a coral's physical environment can cause bleaching (e.g., changes in temperature, salinity, seawater chemistry, light), and the primary cause of mass bleaching is elevated water temperature combined with increased solar irradiance. Some physical factors, however, actually help reduce the intensity of stress or help corals to avoid stress. For example, physical factors that help coral communities avoid heat stress and consequent bleaching by ameliorating the conditions that drive these changes include cooling, shading, screening, and history of exposure.

- 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 in the water column, thus reducing radiation stress, which is a key contributor to the bleaching response.
- History of Exposure: Coral communities that are exposed to extreme conditions regularly are often populated by species with a high tolerance for stress.

Cooling

Local meteorological conditions, bathymetry, and tidal and oceanic currents affect local current patterns and can result in upwelling of deep, cooler water to the surface. Complementary factors such as long-shore or offshore winds, tropical storms, eddies adjacent to reefs, or narrow straits between islands, also may increase mixing and contribute to cooling.

Physical factors that reduce temperature stress:

- Localized upwelling of cool water
- Deep water adjacent to reefs
- Regular exchanges (cooler waters replace warm water)
- Physical factors that enhance water movement and flush toxins
- Permanent strong currents (eddies, gyres, tides)
- Wind
- Topography (narrow channel, peninsulas and points)
- High wave energy
- High tidal range

Shading
Shading can reduce light penetration in the water, and thereby reduce stress. However, in order for shading to be effective, it must be consistent and reliable. For example, heavy cloud cover may offer protection to corals from increased ultraviolet light and ultimately from bleaching, but clouds are not a reliable source of shade. On the other hand, topographical and bathymetric features occur year-round and therefore are reliable indicators of shading.

Physical factors that decrease light stress:

- Shade (from high land profile, undercut coastlines or reef structure)
- Steep slopes and overhangs from coral assemblages and structure

Screening
Similar to shading, screening is a factor that can reduce light penetration in the water, and reduce stress from temperature and light. Sediments from urban and agricultural run-off cause stress and kill corals. However, some corals that live in sheltered, inshore locations may tolerate fluctuating levels of naturally occurring dissolved and suspended matter that color the water. Corals on these sheltered reefs may benefit from the screening of sunlight by suspended particles that scatter light, and by colloids and colored dissolved organic matter that absorb light.

Turbid water caused by excessive nutrient run-off or other land-based sources of pollution do not provide beneficial screening protection to corals. These conditions are harmful and weaken the resilience of corals exposed to them even for short periods.

Physical factors that decrease light stress include the presence of naturally turbid water.

History of Exposure
Corals generally require narrow ranges of certain conditions to survive (e.g., temperature, salinity, light), but some corals have acclimatized to highly stressful conditions at the outer limits of their ranges. A history of exposure to high temperatures can influence the thermal tolerance of corals and enhance their resilience.

For example, corals subjected to warmer than average temperatures prior to a bleaching event can be more thermally tolerant compared to corals that have not been pre-stressed. Healthy corals in areas where thermal variability is high (e.g., in back-reef lagoons) may also be more resistant to thermal stress. Additionally, parts of reefs that regularly experience heat stress conditions, such as reef flats and crests, may be populated by corals that are more tolerant of and resistant to stresses.

Physical factors that reduce temperature stress include the history of exposure to high temperatures and high thermal variability may help corals to be more tolerant of and resistant to temperature stress.

Guidance for Managers

If conservation planners and managers can identify physical factors that help coral communities avoid heat stress and consequent bleaching, then areas with these factors present could be prioritized for protection in marine protected areas.

- Consider the physical factors in the area to evaluate the extent to which cooling occurs in the area. Areas that are consistently cooled by oceanographic factors may experience less thermal stress than adjacent areas, and corals in these cooler areas may be less likely to experience bleaching conditions.
- High diversity coral reefs with a wide range of sizes may also be priorities for protection. A wide range of sizes of corals of a given species indicates a range of ages and therefore serves as a proxy for survival and recovery over time.
- Look for areas with naturally occurring suspended or dissolved matter in the water and healthy coral populations. This may be an area of screening, and corals in these sheltered areas may less vulnerable to bleaching because they are protected from the combination of light and heat stress. These areas should be considered for protection
- Healthy corals in areas that historically have been exposed to high sea temperatures and areas that experience thermal variability may be more resistant to bleaching, thus these areas may also be priorities for protection.

Climate Change: Key Issues for Coral Reefs

This tab focuses on 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 section is to emphasize how significant these problems are and that coral reef managers DO need to pay attention to these global-scale problems.

Table of Contents

Climate Change: Key Issues for Coral Reefs: Training Guidance

Estimated Time
45 minutes – Powerpoint Presentation
30 minutes – Activity: Group discussion

Seating Arrangement/Group Size
Full Session – Up to 25 students (absolute max is 30)

Learning Objectives
By the end of this training students will:
- ✓ Understand current scientific knowledge on climate change
- ✓ Understand the causes of mass bleaching
- ✓ Understand ocean acidification and its potential impacts
- ✓ Understand communication challenges and tips for this topic area

Additionally, content can be added to this presentation to meet the following objectives:
- ✓ Understand the causes and impacts of coral disease

Activity Description
1. Give Powerpoint Presentation: Climate Change: Key Issues for Coral Reefs (45 minutes)
2. Conduct Group Discussion on Climate Change (30 minutes)
    - Divide into small groups of 4-5 participants
    - Assign a facilitator to each small group
    - Facilitators should facilitate a group 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 to their stakeholders. Use the following discussion questions:
        - What indications of climate change have you observed in your region?
        - What habitats do you manage that are susceptible to climate change?
        - Have you witnessed mass bleaching on the reefs in your region?
        - What were the long terms impacts/recovery in your area?
        - 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)?

Materials Needed
- Powerpoint Presentation: Climate Change: Key Issues for Coral Reefs (Flash drive)
- One flip chart per group
- Multi-colored markers – 1 pack per group

Notes to the Instructor/Additional Resources

- 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) http://www.noaa.gov/video/administrator/acidification/index.html. It is very simple and can be more effective than reviewing the chemistry. 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.

Climate Change: Key Issues for Coral Reefs: Background Information

1. Climate and Ocean Change

There is strong international consensus that the world is experiencing global climate change, the rate of climate change is increasing, and that much of the change is due to human activities.

Increasing greenhouse gases, from a variety of human activities (burning fossil fuels for heat and energy, deforestation, fertilizing crops, raising livestock, and producing some industrial products) is dramatically affecting coral reef ecosystems.

Coral reef ecosystems are also threatened by a combination of other stressors including overfishing, coastal development, pollution, and disease. Over the last several decades, global climate change, in combination with local stressors, has resulted in major declines in coral reef ecosystems worldwide.

1.1. Warming Seas

Projections of Changes in Sea-Surface Temperature (SST)

Human activities, such as the burning of fossil fuels, cement production, and deforestation, have increased greenhouse gas concentrations in our atmosphere. This accumulation of carbon dioxide and other heat-trapping gasses has increased atmospheric temperatures, warming the Earth between 0.6-0.8°C since 1880, and projected to further warm it between 2-4°C by 2100, mostly due to human activity (IPCC 2007). This increase has led to a corresponding increase in ocean temperatures, particularly in the surface of the ocean. Warmer oceans may also lead to more powerful storms and increases in sea, which can dramatically affect coral reef ecosystems.

Impacts on Coral Reef Ecosystems

Corals can tolerate a narrow range of environmental conditions and live near the upper limit of their thermal tolerance. Therefore, corals are very sensitive to changes in sea temperature. Abnormally high ocean temperatures (e.g., sea temperatures 1–2°C greater than average summer maxima) can cause coral (Glynn 1993; Hoegh-Guldberg 1999), and can result in coral mortality, declines in coral cover and shifts in the population of other reef-dwelling organisms. Stress resulting from elevated SSTs also increases the incidence of coral disease. If the thermal stress decreases, corals may recover, but if the stress is sustained, mortality can occur.

Elevated SSTs combined with high solar irradiance have been linked to large scale coral bleaching events (Glynn, 1996; Hoegh-Guldberg 1999). The frequency and severity of large-scale bleaching events are expected to increase as SSTs continue to warm under global climate change, leading to major concerns about the future of coral reefs worldwide (Donner et al. 2005; Hoegh-Guldberg et al. 2007; IPCC 2007). Climate projections suggest that thermal thresholds for corals will be exceeded annually after 2050, if not sooner (Donner 2009).

The degradation of coral reefs caused by widespread bleaching and impaired growth may adversely affect adjacent ecosystems including mangrove and seagrass systems that depend on the reefs to provide shelter from wave action (Fernando et al. 2005). Thermal stress is also projected to result in distribution shifts, changes in patterns of sexual reproduction, and altered growth rates and metabolism for mangroves and seagrasses (Field 1995; Short and Neckles 1999). Elevated temperatures may increase the growth of competitive algae which can overgrow seagrasses and reduce the available sunlight needed for survival.

The ability of coral reefs to acclimate or adapt to global warming is currently a topic of research (Baker et al. 2004; Hoegh-Guldberg et al. 2007a; Baird et al. 2009). While some studies suggest that thermal adaptation and/or acclimatization is possible, the ability of corals to adapt/acclimate to warming is in question because of the steepness of the predicted global warming trend and the erratic nature of thermal events (Anthony and Marshall 2009).

1.2. Sea-Level Rise

Projections of Sea-level Rise

Global sea-level rise is caused by two main factors: 1) thermal expansion (ocean water warms and expands) and 2) the contribution of ice sheets (e.g., from glaciers, land-based, ice sheets, and sea ice) due to increased melting.

By 2100, thermal expansion and glacial melting are expected to raise sea-level rise by 0.18 to 0.59 m, based on climate models (IPCC 2007). However, such projections do not take into account the contribution of the Greenland and West Antarctic ice sheet which could significantly increase the extent of sea-level rise. Therefore, scientists suggest that a 1-2 m rise in sea level by 2100 is likely and up to 4 m a strong possibility, when taking into account thermal expansion of ocean water, melting of ocean glaciers, ice sheet disintegration, and an acceleration of sea-level rise in the 20th century (IPCC 2007; Rahmstorf 2007; McMullen and Jabbour 2009; Vermeer and Rahmstorf 2009; Grinsted et al. 2009; Jevrejeva et al. 2010).

Over the last half century, the global average sea level rose by about 2-3 mm per year (IPCC 2007; Nicholls and Cazenave 2010). Based on this rate, many scientists suggest that sea-level rise will have only negligible impacts on coral reefs because the projected rate and magnitude of sea-level rise are within the potential accretion rates (i.e., growth rate) of most coral reefs and many reefs are currently subjected to tidal regimes of several meters (Anthony and Marshall 2009).

Impacts on Coral Reef Ecosystems

Recent research warns that even though the rapid growth rate of many corals (e.g., 2 to>30 mm/year) seems sufficient to keep pace with annual sea-level rise projections, the overall net vertical accretion of reefs may be much slower than the growth of individual coral colonies (Hubbard et al. 2008). In addition, scientists are also concerned that existing threats to reefs (e.g., increasing sea temperatures, ocean acidification, disease, and overfishing) reduce corals' ability to keep pace with sea-level rise. In particular, ocean acidification may significantly slow both the rates of coral growth and reef accretion, making it even more difficult for corals to keep up.

Sea-level rise is likely to increase sedimentary processes that potentially interfere with photosynthesis, feeding, recruitment, and other key physiological reef processes (Field et al. 2011). For example, it can cause increased sedimentation due to shoreline erosion which could smother reefs or reduce sunlight needed for photosynthesis. Even small increases in sea level (e.g., 0.2 m) can increase turbidity on fringing reefs through two mechanisms: 1) increased re-suspension of fine sediment on reef flats (the inner portion of fringing reefs closer to sediment sources) and 2) increased coastal erosion and transport of fine sediment to adjacent reefs. Smothering of reef structures led to a rapid retreat of reefs during the rapid and large (6 meter) sea-level rise of the last interglacial (Blanchon et al. 2009).

Sea-level rise can also inundate and erode coastal habitats such as mangroves and turtle nesting beaches. Mangroves may be able to adapt if sea-level rise occurs slowly enough, if adequate expansion space exists, and if sufficient sediment exists to continue to accrete vertically to compensate for sea-level rise.

1.3. El Nino Southern Oscillation

The El Niño Southern Oscillation (ENSO) is a periodic shift of the ocean-atmosphere system in the tropical Pacific that impacts weather around the world. This anomaly happens every 3-7 years (5 years on average) and typically lasts nine months to two years. It is associated with floods, droughts, and other global disturbances. During an ENSO event, there is a rise in air pressure over the Indian Ocean, Indonesia, and Australia, and a fall in air pressure over Tahiti and the rest of the central and eastern Pacific Ocean. Trade winds in the south Pacific weaken or head east, and warm water spreads eastward from the west Pacific and Indian Ocean to the east Pacific. This leads to extensive drought in the western Pacific and rainfall in the normally dry eastern Pacific.

During normal, or non-El Niño conditions, the trade winds blow west across the Pacific. These winds pile up warm surface water in the west Pacific so that the sea surface is about one half meter higher around Indonesia than around Ecuador. Ocean upwelling occurs off the coasts of Peru and Ecuador bringing nutrient-rich cold water to the surface and increasing fishing stocks. The western side of the equatorial Pacific is characterized by warm, wet, low-pressure weather as the collected moisture is dumped in the form of typhoons and thunderstorms.

While El Niño is characterized by unusually warm ocean temperatures in the central to eastern equatorial Pacific, La Niña is characterized by unusually cold ocean temperatures in this region but warm waters in the western Pacific. In most years the warming lasts only a few weeks or a month, after which the weather patterns return to normal and fishing improves. However, when El Niño conditions last for many months, more extensive ocean warming occurs and its economic impact on local fishing for an international market can be serious.

Projections of ENSO

ENSO events are a natural process and have been present for thousands if not millions of years. ENSO events are not caused by climate change, they are caused by the interaction between the surface layers of the ocean and the overlying atmosphere in tropical Pacific. However, it is certainly possible that global warming will change the way the El Niño cycle behaves.

Since the mid-1970s, there have been more frequent and persistent El Niño episodes than La Niña episodes. Changes in precipitation over the tropical Pacific are related to this change in the ENSO, which has also affected the pattern and magnitude of sea-surface temperatures. However, it is unclear as to whether this change in the ENSO cycle is due to normal variation or is related to global warming.

Although some scientists hypothesize that warmer global sea surface temperatures might lead to an increase in El Niño events, whether the occurrence of El Niño changes with climate change is still an active area of research. Studies of historical data suggest that recent El Niño variation is most likely linked to global warming (Zhang et al. 2008). In contrast, a more recent study suggests that climate change is not expected to affect the extent or frequency of ENSO over the 21st century, but could worsen its impacts (Stevenson et al. 2011).

Predicting ENSO Events

Scientists are unsure what changes will happen to ENSO in the future, and climate modelers make different projections (Merryfield 2006). More frequent and stronger El Niño events may occur only in the initial phases of global warming and then such events may become weaker. El Niño events may continue to strengthen and increase into the future. Due to the major impact on climate patterns caused by El Niño and La Niña it is critical to be able to predict when these events will occur.

A number of tools are available for monitoring, research, and forecasting ENSO events, including satellite and in-ocean observations that provide near real-time data on surface winds, ocean temperatures, currents, and other parameters. Currently, seasonal predictions are generally accurate on average, but individual events are challenging to predict. Experts suggest that El Niño or La Niña predictions that are greater than 9 months into the future may not be accurate. Better predictions can be made by examining several models rather than just one model.

Impacts on Coral Reef Ecosystems

El Niño and La Niña can both have severe impacts on coral reef ecosystems, and particularly on coral reefs. Globally, ENSO generated massive bleaching and coral mortality during 1982-1983 (Glynn 1984, Glynn and deWeerdt 1991), 1997-1998 (Bruno *et al*. 2001, McClanahan *et al*. 2008), 2002-2003 (Strong *et al*. 2003), 2005 (Wilkinson and Souter 2008), and 2010, and contributed to the likely extinction of a coral species (Glynn & deWeerdt 1991).

- ***1982-1983 El Niño event***
    - Mass bleaching observed in Panama (Glynn 1984)

    - Warm sea surface temperatures (SSTs) associated with the El Niño event were identified as the cause of death for over 50% of corals in Panama and over 99% of the corals in the Galapagos (Glynn and D'Croz 1990; Glynn 1993)

- ***1997-1998 El Niño event***
    - Resulted in unprecedented coral bleaching and coral death globally (Wilkinson et al. 1999)
    - About 70-80% of all shallow water corals were killed on many Indo-Pacific reefs and the Great Barrier Reef
    - Reefs in the Florida Keys experienced mild to severe bleaching (NMFS 2001; NMS 2000)
    - Much of the bleaching coincided with a large El Nino event, immediately switching over to a strong La Nina

- ***2005 El Niño event***
    - High ocean temperatures in the tropical Atlantic and Caribbean resulted in one of the worst bleaching event ever recorded in the region
    - Thermal stress during the 2005 event exceeded any observed from the Caribbean in the prior 20 years, and regionally-averaged temperatures were the warmest in over 150 years (Eakin et al. 2010)

- ***2010 El Niño event***
    - One of the worst years for coral bleaching since the 1997-1998 El Niño event
    - Resulted in extensive bleaching and mortality across the Indian Ocean and Southeast Asia (bleaching extended from the Seychelles in the west to Sulawesi and the Philippines in the east and included reefs in Sri Lanka, Burma, Thailand, Malaysia, Singapore, and many sites in western and eastern Indonesia) and also severe bleaching occurred in parts of the Caribbean (e.g., Venezuela and Panama)

While there are correlations between the widespread coral bleaching in 1997-1998 and the El Niño-Southern Oscillation system, the patterns are unclear. For example, during the 1997-1998 event, observed bleaching in the eastern Pacific correlated with the El Niño event. By contrast, the bleaching in Southeast Asia coincided with the subsequent 1998-1999 strong La Niña, which brought warm waters to the western Pacific. The Indian Ocean bleaching at that time corresponded to warming during the El Niño, while bleaching in parts of the Caribbean followed a typical pattern of bleaching in the summer following the El Niño.

Large-scale bleaching events, however, do not necessarily occur in conjunction with major El Niño or La Niña events. The largest bleaching event recorded in the Caribbean occurred in 2005, following a mild El Niño, and was poorly connected to El Niño climate patterns (Eakin et al. 2010). Despite the limitations in knowledge of how El Niño and La Niña affect coral bleaching events, scientists are concerned that increases in SSTs globally, and potential increases in El Niño events, can endanger the survival of coral reefs.

1.4. Changes in Storm Patterns

Projections of Changes in Storm Patterns

Determining whether tropical storms have changed in response to a warming climate has been widely debated and often with conflicting results. Several factors make it difficult to determine if and how climate change is affecting storm patterns. For example, large natural variability in the frequency and intensity of tropical storms (e.g., due to the El Niño- Southern Oscillation) complicates the detection of long-term trends and their attribution to increasing greenhouse gases. Other factors include limitations in the availability and quality of global historical records of tropical storms, inconsistency in data observation methods, the localized nature of the events, and the limited areas where studies have been conducted. Additionally, even if there is a change in storm frequency or intensity, what matters most is how the storm patterns change (i.e., where they go). Scientists have no reliable way of predicting how this may change in the future.

Despite these challenges, many future projections based on high-resolution models suggest that anthropogenic warming may cause tropical storms globally to be more intense on average (with intensity increases of 2–11% by 2100). While some studies consistently project decreases in the globally averaged frequency of tropical cyclones, substantial increases are projected in the frequency of the most intense cyclones (Knutson et al 2010).

Since the mid 1970's, global estimates of the potential destructiveness of hurricanes show an upward trend strongly correlated with increasing tropical sea-surface temperature (IPCC 2007). The number of strong hurricanes (category 4 and 5) increased by about 75% since 1970 with largest increases observed in the North Pacific, Indian, and Southwest Pacific Oceans. The frequency of hurricanes in the North Atlantic has also been above normal over the last decade. However, improvements in our ability to observe cyclones may have biased these estimates (Knutson 2010).

Impacts on Coral Reef Ecosystems

If tropical storms increase in intensity, then coral reefs will need longer times for recovery from impacts between storm events. Direct physical impacts from storms include erosion and/or removal of the reef framework, dislodgement of massive corals, coral breakage, and coral scarring by debris. Recent research suggests that increasing storm impacts are also likely to cause fragile branching species (responsible for most structural complexity in reef) to decline more rapidly than the proportion of massive corals, resulting in low structural complexity on impacted reefs (Fabricius et al. 2008).

In addition, stronger storms also lead to greater coral damage due to increased flooding events, associated terrestrial run-off of freshwater and dissolved nutrients from coastal catchments, and changes in sediment transport (leading to smothering of corals). Whether the intensity of storms becomes more frequent, coral skeletons are likely to become more susceptible to breakage under ocean acidification and therefore more susceptible to storm damage (Madin et al. 2008).

Storm damage on coral reefs is extremely patchy (Connell et al. 1997) due to the substantial differences between storms in terms of their intensities, size, and movement. Damage can vary from removal of entire coral outcrops (over 10s to 100s of meters) in the direct path of a storm, to individual colony damage in more sheltered areas (Halford et al. 2004). In addition to storm frequency and intensity, damage may also be driven by disturbance history, level of coral cover, type of coral community, and environmental factors such as exposure and circulation (Osborne et al. 2011). Recovery is also highly variable and depends upon interactions of numerous factors, e.g., scale of the disturbance, availability of larvae from surviving corals, availability of substrate for coral settlement, and the type of coral community that existed at the time of the disturbance (Halford et al. 2004). In addition to damaging coral reefs, changes in storm patterns also threaten associated coral reef habitats such as mangroves. For instance, large storm impacts have resulted in massive mangrove mortality in the Caribbean (Cahoon et al. 2003).

Storms can sometimes benefit corals

In some cases, large storms can actually be beneficial to coral reefs. For example, hurricanes can mitigate coral bleaching by causing short-term reductions in local sea temperatures, thus reducing thermal stress (Manzello et al. 2007). Hurricanes can also reduce the abundance of coral colonies more susceptible to thermal stress, e.g., branching and tabular colonies which can dominate reefs that rarely experience storms, thus reducing the potential for future storms to cause further damage. Finally, tropical storms can temporarily remove excessive macroalgae, which can restrict coral recruitment and growth, although post-hurricane damage to coral cover and stirring of nutrients may lead to shifts to algal-dominated communities (Hughes 1994). Clearly the combination of damage and cooling can play an important role in reef dynamics (Carrigan and Puotinen 2011).

2. Bleaching

What is Coral Bleaching?

Most reef-building corals contain zooxanthellae, which are single-celled dinoflagellates that live within the coral’s tissue. Corals and zooxanthellae have a symbiotic relationship [a symbiotic relationship is a close ecological relationship between the individuals of two (or more) different species that may, but does not necessarily, benefit each species.] Zooxanthellae provide carbohydrates to the coral through photosynthesis, allowing their host (the coral) to direct resources toward growth and constructing its calcium carbonate skeleton. The coral, in return, provides the zooxanthellae with nutrients and a protected environment.

Bleaching is a stress response that occurs when the coral-zooxanthellae relationship breaks down and the zooxanthellae are expelled from the coral host or when pigments within the algae are degraded.

The loss of zooxanthellae makes the white calcium carbonate coral skeleton visible through the transparent tissue, making the coral appear bright white or 'bleached'. Corals can survive for some time (e.g., several days or months) without their zooxanthellae, but their ability to survive depends upon the level and type of stress and the sensitivity of the coral. If stressors persist, corals may then starve and die. Bleaching also occurs in other animals with zooxanthellae, such as foraminifera, sponges, anemones and giant clams.

What Causes Bleaching?

Coral bleaching is a response to stress and can be caused by a number of factors. Sources of stress that can lead to coral bleaching include:

- Elevated or reduced water temperatures
- High solar irradiance from ultraviolet light and photosynthetically available radiation (PAR- *photosynthetically available radiation* refers to the spectral range (wave band) of solar radiation from 400-700 nanometers (the visible wavelengths and the spectrum used by plants for photosynthesis) that is absorbed by the chlorophyll molecule.)
- Disease
- Pollution
- Changes in salinity (e.g., salinity shock from heavy rains or floods)
- Sedimentation from activities such as dredging
- Exposure to air (e.g., due to low tide)
- Changes in water chemistry (e.g., ocean acidification)

These sources of stress can contribute to localized bleaching events (tens to hundreds of meters), but mass coral bleaching events occur at regional scales, often extending over tens to hundreds of kilometers. The primary cause of mass bleaching is elevated water temperature combined with solar irradiance.

2.1. Bleaching Biology

Elevated seawater temperatures in combination with strong sunlight cause thermal stress in corals. This stress can cause disruption of normal photosynthetic processes in the coral's zooxanthellae which leads to coral bleaching.

Role of Temperature and Light

The main trigger of large-scale bleaching events is an increase in water temperatures above the normal summer maximum. At elevated temperatures, the photosynthetic system of zooxanthellae is easily overwhelmed by incoming light (specifically the bandwidths important for photosynthesis, known as PAR) leading to production of reactive oxygen species. These are a source of oxidative stress in the coral's tissue, causing the coral to expel zooxanthellae to avoid further tissue damage. While increased temperatures are the trigger for bleaching, light is also an important factor. Increased irradiance can exacerbate bleaching risk, while corals that are partially shaded can tolerate higher temperatures before bleaching.

Recovery from bleaching

Without the zooxanthellae to support their metabolic processes, corals begin to starve. Should water temperatures return to normal conditions soon enough, corals can survive a bleaching event. Where bleaching is not too severe, the zooxanthellae can repopulate from the small numbers remaining in the coral's tissue, returning the coral to normal color over a period of weeks to months. Some corals, like many branching corals, cannot survive for more than 10 days without zooxanthellae. Others, such as some massive corals, are capable heterotrophs (which rely on consuming organic material for nutrition, as opposed to autotrophs which can manufacture their own food) and can survive for weeks or even months in a bleached state by feeding on plankton. Even corals that survive are likely to experience reduced growth rates, decreased reproductive capacity, and increased susceptibility to diseases.

Variations in bleaching susceptibility
Corals vary in their susceptibility to bleaching. Consistent patterns of susceptibility can be seen among coral species, with a general trend of higher susceptibility in more intricate, branching forms and lower susceptibility in massive species, especially those with fleshy polyps.

Corals can also acquire a greater tolerance to bleaching stresses if they are constantly exposed to higher temperatures or greater irradiance. Corals on reef flats, for example, will often be able to tolerate much higher water temperatures than colonies of the same species inhabiting reef slopes.

The type of zooxanthellae can also influence bleaching susceptibility. There are at least nine groups (called clades) of zooxanthellae currently recognized, and there may be many species within these groups. Zooxanthellae clades vary in their ability to tolerate elevated temperatures, and some corals have heat-resistant clades, and are therefore, more resistant to bleaching. However, corals with heat-resistant clades tend to grow more slowly, creating evolutionary trade-offs in the symbiotic relationship that maintain a diversity of clade-coral relationships.

2.2. Mass Bleaching

Coral bleaching is a common response of a coral under stress, and isolated colonies or small patches of bleached coral are not necessarily cause for concern. However, mass bleaching events that span tens or even hundreds (and sometimes thousands!) of kilometers can affect entire ecosystems and are a significant cause for concern for coral reef managers and stakeholders.

Mass bleaching events are primarily triggered by sea temperatures exceeding the normal summer maximum for prolonged periods (weeks). The frequency and severity of mass-bleaching events have been increasing over the last few decades, causing reef degradation at a global scale. These events are expected to occur even more often as sea-surface temperatures continue to rise under global climate change (Donner et al. 2005 & 2009; Hoegh-Guldberg et al. 2007; IPCC 2007).

Forecasting Mass Coral Bleaching Events
Whether a reef bleaches during warming events depends on a variety of factors, both physical and biological. However, the strong link to temperature provides a reliable basis for predicting the probability and timing of mass bleaching events.

Degree heating weeks (DHWs) are a metric used by NOAA's Coral Reef Watch program to help coral reef managers worldwide monitor bleaching risk. Because coral bleaching risk is determined by both the size of the temperature anomaly and its duration (i.e., how far the temperature is above the bleaching threshold and how long it has stayed above that threshold), degree heating weeks (DHWs) are used to represent the accumulation of thermal stress for corals. One DHW is equivalent to one week of sea-surface temperatures one degree Celsius greater than the expected summertime maximum. Two DHWs are equivalent to two weeks at one degree above the expected summertime maximum OR one week of two degrees above the expected summertime maximum. At 4 DHWs, conditions have become stressful for corals, and bleaching events become likely. Severe stress and possibly mortality is likely to occur at 8 DHWs or greater.

While high water temperature and bright sunlight are the primary triggers of mass bleaching, calm and clear conditions with minimal current can exacerbate the stress and intensify bleaching. Lack of wind and current results in less mixing of water layers, clearer seas, and deeper penetration of PAR.

Other factors that influence bleaching risk
Bleaching severity can vary across a reef system, even within a mass bleaching event. A range of factors will influence the timing and severity of bleaching, especially at the scale of individual reefs or areas. These include the intensity of solar irradiance, the amount of light that penetrates the water column, amount of mixing of cool waters and the condition (pre-existing stressors) of corals.

The response of a coral community to stress also depends on the abundance and composition of corals. Reefs dominated by resistant coral types may bleach less severely, or bleach later, than reefs dominated by susceptible species.

Factors that reduce these stressful conditions, such as cloud cover, strong winds, or tropical storms may be enough to protect the corals from bleaching. One physical factor that is likely to increase resistance to bleaching is shading. When shade is present, either due to weather conditions or physical location of a coral, bleaching is less likely to occur.

3. Ocean Acidification
This section provides information on the problem of ocean acidification, including the basics of ocean carbon chemistry and biological and socioeconomic impacts.

Increasing atmospheric CO_2 is absorbed by the ocean and leads to changes in the ocean's carbon chemistry. Ocean acidification occurs when CO_2 in the atmosphere reacts with water to create carbonic acid, decreasing both the pH of seawater (increasing seawater's acidity) and the concentration of the carbonate ion. The carbonate ion is essential for calcification, a process needed for all marine animals that create a calcium carbonate skeleton, like corals.

Although the chemistry of this effect is well understood, the extent of impacts of ocean acidification on marine ecosystems and human well-being are not well known. Warming seas and ocean acidification are already affecting reefs by causing mass coral bleaching events and slowing the growth of coral skeletons, which threatens coral reef resilience (Pecheux 2002; Kleypas and Langdon 2006; Anthony et al. 2008 & 2011).

Recent research demonstrates that severe acidification and warming alone can reduce reef resilience (through impaired coral growth and increased coral mortality) (Anthony et al. 2008 & 2011). In addition, ocean acidification is likely to make corals more susceptible to breakage from tropical storm impacts. The ability of corals to keep pace with sea level rise may also be reduced due to decreased growth rates caused by ocean acidification. Finally, reefs that are already threatened by local stressors are likely to be more vulnerable to ocean acidification (Carilli et al. 2009; Anthony et al. 2011). Management of local-scale stressors will be increasingly critical to keep reefs healthy in the face of increasing global stressors.

3.1. Ocean Carbon Chemistry

The concentration of atmospheric CO_2 has increased dramatically since the Industrial Revolution [from around 280 parts per million (ppm) in preindustrial times to 392 ppm in 2011], primarily due to human activities such as the burning of fossil fuels and changes in land-use (IPCC 2011). The ocean plays an important role in reducing atmospheric CO_2 by absorbing about ¼ of CO_2 that has been released each year into the atmosphere (Sabine et al. 2004; Le Quéré et al. 2009). This process helps to reduce the impacts of global warming associated with increasing emissions, but it has come at a cost: ocean acidification.

Changes in ocean chemistry

When CO_2 is absorbed by the ocean, chemical reactions occur. In particular, carbonic acid is formed and hydrogen ions are released, and as a result the pH of the ocean surface waters decrease (making them more acidic). When hydrogen ions are released in seawater, they combine with carbonate ions to form bicarbonate. This process lowers the carbonate ion concentration. The reduction of available carbonate ions is a problem for marine calcifiers (corals, crustaceans, and mollusks) who need the carbonate ions to build their shells and skeletons.

Changes in the carbonate ion concentration in seawater can affect the saturation state (and hence biological availability) of several types of calcium carbonate (e.g., calcite, aragonite, or high-magnesium calcite (Feely et al. 2009)). In many parts of the ocean, the seawater is supersaturated with respect to these calcium carbonate minerals, meaning that there is enough calcium carbonate for calcifying organisms to build their skeletons and shells. However, continued ocean acidification is causing many parts of the ocean to become undersaturated with these types of calcium carbonate, thus adversely affecting the ability of some organisms to produce and maintain their shells.

The pH of the surface ocean has fallen by 0.1 pH units since the beginning of the Industrial Revolution (Feely et al. 2004). While this may not sound like a lot, the pH scale is logarithmic (a scale of measurement that displays the value of a quantity using intervals corresponding to orders of magnitude, rather than a standard linear scale). For example, a chart with a vertical axis with equally spaced increments labeled 1, 10, 100, 1000, instead of 1, 2, 3, 4. Each unit increase on the logarithmic scale represents an exponential increase in the underlying quantity for the given base (10, in this example) and this change represents a 30% increase in acidity. As the oceans continue to absorb CO_2, they will become increasingly more acidic. Ocean pH is projected to drop an additional 0.4 pH units by 2100 under a high CO_2 emission scenario (IPCC 2007), with carbonate saturation levels potentially falling below those required to sustain coral reef accretion (Royal Society 2005; Hoegh-Guldberg et al. 2007; Silverman et al. 2009). Such changes in the carbon chemistry of the open ocean probably have not occurred for more than 20 million years (Feely et al. 2004).

While anthropogenic CO_2 emissions are driving acidification at global scales, processes occurring at local scales can also affect ocean chemistry. For example, freshwater inputs, pollutants (e.g., acidic fertilizers, chemicals discharged from water treatment and power plants), and soil erosion have the potential to acidify coastal waters at substantially higher rates than atmospheric CO_2 alone (Kelly et al. 2011).

3.2. Biological Impacts

Changes in ocean chemistry can have extensive direct and indirect effects on marine organisms and the ecosystems in which they live. Studies of marine calcifiers (corals, crustaceans, and mollusks) indicate that most, but not all, exhibit reduced calcification with increased ocean acidification (Fabry et al. 2008; Kroeker et al. 2010).

Impacts on marine organisms

A growing number of studies have demonstrated adverse impacts on marine organisms as a result of ocean acidification, including the following (Orr et al. 2005; Raven et al. 2005; Kleypas et al. 2006; Kurihara 2008):

- Decreased rate of skeletal growth in reef-building corals
- Reduced ability to maintain a protective shell among free-swimming zoo-plankton (zooplankton include “animal plankton”, mainly small crustaceans and fish larvae, and form the base of most marine food webs)
- Reduced rate of calcium carbonate production in marine macroalgae (crustose coralline and green algae)
- Reduced survival of larval marine species, including commercial fish and shellfish
- Impaired developmental stages of invertebrates (fertilization, egg cleavage, larva, settlement and reproduction)
- Excessive CO_2 levels in the blood (CO_2 toxicity) of fish and cephalopods and significantly reduced growth and fecundity in some invertebrate species

Declining pH (increasing acidity) may affect organisms in ways that extend beyond declining calcification or metabolic performance, including:

- Interactions between species during different life stages
- Shifting competitive pressures (e.g., algae outcompeting corals)
- Alterations in predation, which will come into play as communities respond to acidification
- Alteration of fish larvae behavior (due to impaired sensory function in larval fish) and reduced recruitment success (Munday et al. 2010)

Interactions with other stressors (e.g., nutrient input, increased sea surface temperature, and sea level rise) will also affect how marine communities will change in response high CO_2 conditions.

Impacts on calcification

One of the most critical effects of increasing ocean acidity relates to the production of shells, skeletons, and plates from calcium carbonate, a process known as calcification. Acidification shifts the equilibrium of carbonate chemistry in seawater, reducing pH and the concentration of carbonate ions available for corals and other marine calcifiers to use to build their skeletons. This decreases the rate and amount of calcification among many marine organisms that build external skeletons and shells, ranging from plankton to shellfish to reef-building corals.

The reduction of dissolved carbonate ions in seawater has many implications for coral reef ecosystems. Since reef-building corals need carbonate to build their skeletons, decreasing carbonate ion concentrations will likely lead to weaker, more brittle coral skeletons and slower coral growth rates. In the future this may cause coral reefs to erode faster than they can calcify, thus decreasing the ability of coral species to compete for space.

For corals and other calcifiers like sea urchins and shellfish, reductions in calcification may:

- Increase corals' susceptibility to bleaching and disease
- Decrease the ability of organisms to fend off predators and compete for food and habitat
- Alter behavior patterns
- Reduced capacity to tolerate ultraviolet radiation and increased rates of bioerosion and greater damage from cyclones

Laboratory studies have examined the effects of ocean acidification 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 CO_2 (Kleypas et al. 2006). A recent study of brain corals in Bermuda found that calcification rates have declined by 25% over the past 50 years and ocean acidification is a likely contributing factor (Cohen 2008).

3.3. Socioeconomic Impacts

The ecological impacts of ocean acidification on ecosystems are not well understood. Therefore, it is difficult to predict how ocean acidification will impact human communities. Because acidification affects fundamental processes related to the overall structure and function of marine ecosystems, any significant change could have far-reaching consequences for the oceans of the future and the billions of people that depend on marine resources for their food and livelihoods.

Commercial and Recreational Fisheries
As ocean acidification affects the ability of marine organisms to form shells and skeletons, it is likely to decrease the abundance of commercially important shellfish species such as clams, oysters, and sea urchins. This affects the human communities that depend upon these resources for food and/or livelihoods (Cooley et al. 2009).

In addition, acidification is likely to affect marine food webs and lead to major changes in commercial fish stocks (Cooley and Doney 2009). Ocean acidification influences the structure and productivity of primary and secondary benthic and planktonic production, which can affect the productivity of fish communities and higher trophic levels. For example, young salmon prey on pteropods, a type of zooplankton that is highly vulnerable to ocean acidification. Additionally, the interaction of acidification with thermal tolerance may affect the temperature-dependent ranges of many fish species.

Decreases in abundance of fishes and changes to marine food webs threaten the protein supply and food security of millions of people, as well as the multi-billion dollar fishing industry.

Coastal Communities and Associated Economies
Ocean acidification will likely impact coastal communities and economies. Coral reefs provide fish habitat, generate billions of dollars in tourism, protect shorelines from erosion and flooding, and provide the foundation for biodiversity. For many communities, new economic development is dependent on coastal tourism. Healthy coral reefs generate tourist dollars and provide coastal protection for infrastructure (such as hotels and resorts).

Increased impacts of climate change
Ocean acidification, along with warming surface waters and changes in ocean mixing, may reduce the ability of the ocean to absorb CO_2. This results in more CO_2 in the atmosphere and increases the impact of ocean acidification on the climate. Because CO_2 is the primary greenhouse gas contributing to climate change, increased CO_2 contributes to increases in global temperatures and associated changes in sea level, storm and precipitation patterns. When the ocean's ability to absorb CO_2 is reduced, humans are likely to feel the impacts of climate change more severely. This reduction also makes it more difficult and more expensive to stabilize atmospheric CO_2 concentrations.

4. Coral Disease

4.1. Causes of Coral Disease

A disease is classified as any impairment of vital body functions, systems, or organs. Diseases are a natural aspect of coral populations and are one mechanism by which population numbers are kept in check. Disease involves an interaction between the coral host, a pathogen, and the reef environment.

Coral diseases can be caused by bacteria, viruses, protozoa, or fungi (Harvell et al. 2007), and can cause significant changes in reproduction rates, growth rates, community structure, species diversity, and abundance of reef-associated organisms (Loya et al. 2001).

Coral diseases have increased in frequency, intensity, and geographic range over the last several decades. Scientists do not know if the emergence of disease outbreaks is due to the introduction of novel pathogens or due to changes in existing pathogens that may be caused by deteriorating environmental impacts and/or reduced host resistance. Scientists do know, however, that coral diseases combined with hurricane damage, coral bleaching, and other natural stressors are resulting in widespread coral mortality.

Many coral diseases have not been thoroughly characterized and the causative agents of many diseases remain uncertain. This is still an area of considerable research. This section of the training guide provides current information on what is known about coral diseases including the causes (including environmental drivers and modes of transmission) and impacts to coral reef ecosystems. This information is essential to help managers predict impacts, understand how current reef management practices and human impacts affect the spread and severity of diseases, and make informed management decisions. The global increase in coral diseases presents serious concerns for coral reef managers and stewards of tropical marine ecosystems.

4.2. Disease Impacts

Coral disease outbreaks can lead to an overall reduction in live coral cover and reduced colony density. In extreme cases, disease outbreaks can initiate community phase-shifts from coral- to algal-dominated communities. Coral diseases can also result in a restructuring of coral populations (Borger 2005), for example a shift from long-lived, slow-growing massive reef builders to communities dominated by smaller, shorter-lived corals (Bruckner and Bruckner 2006).

In addition to the loss of coral tissue, disease may cause significant changes in reproduction rates, growth rates, community structure, species diversity, and abundance of reef-associated organisms (Loya et al. 2001).

Global Patterns

Coral reef diseases are distributed around the world. The following map shows where some of the major diseases are located globally.

The Caribbean has been referred to as a “hot spot” for coral disease because of a rapid emergence of new and extremely virulent diseases, increased frequency of events, and rapid spread of emerging diseases among new species and regions (Harvell et al. 2007). Although only 8% of all coral reefs (by area) are found in the Caribbean, over 70% of all disease reports come from this region (Harvell et al. 2007). Furthermore, at least 82% of coral species in the Caribbean are host to at least one disease (Bruckner 2002).

A number of studies indicate that disease prevalence in the Indo-Pacific region, American Samoa (Aeby 2009) and Hawaiʻi (Aeby et al. 2009) is currently quite low. However, across the Indo-Pacific region, diseases appear to be exhibiting a rapid expansion in range and types of disease since 2000 (Galloway et al. 2009). As efforts increase to document coral diseases globally, the lists of species affected by disease, locations where diseases are reported, and prevalence of those diseases, are steadily increasing.

Managing for Reef Resilience

This tab provides information on actions that managers can take to support the natural resilience of reef systems. Globally, reefs are facing increasing pressures from local and global stressors, resulting in degraded reefs in most regions. At the same time, demand for goods and services from reef ecosystems – and their importance to coastal populations – is escalating. In combination, these trends present a major challenge for coral reef managers, who are charged with conserving biodiversity *and* managing resources for sustainable use. This tab also provides information on the components of effective management and how to use resilience assessments to inform management decisions.

Table of Contents

Managing for Reef Resilience: Training Guidance

Estimated Time
15 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 training students will:
- ✓ Review and discuss resilience-based management action options
- ✓ Understand the mechanics of a resilience assessment and how to use the results to prioritize and target action options.

Activity Description
1. Give Powerpoint Presentation: Managing for Reef Resilience (15 minutes)

2. Conduct Activity Part 1: Identifying Action Options (50 minutes)
   - Divide into small groups of 4-6 participants
   - Distribute Resilience Management Activity Participant handout
   - Give the participants 5 minutes to brainstorm on their handout
   - 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 (Use the Facilitator Handout (Flash drive) as guidance)

3. Conduct Activity Part 2: Assessment, Prioritizing, and Targeting Actions (40 minutes)
   - Give powerpoint to large group to introduce the activity; explain to your group that they will 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
   - Ask your group to use their handout and review the matrix and the map
   - Groups will answer the questions on Part 2 of the handout

4. OPTIONAL: Debrief Activity with full group (10 minutes)

Notes to the Instructor/Additional Resources

- 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

Materials Needed

- Powerpoint Presentation: Managing for Reef Resilience (Flash drive)
- Flip charts and pens to record any discussion following the presentation
- Participant Handout Resilience Management Activity (Flash drive)
- Facilitator Handout Resilience Management Activity (Flash drive)

**Resilience and coral reef management decision-making:
Participant Handout**

These **learning objectives** form the major parts of the activity/discussion:
1. Review and discuss resilience-based management action options
2. Increase understanding of the mechanics of a resilience assessment and how to use the results to prioritize and target action options

1. Resilience-based management action options

Instructions: Answer the question below during a guided discussion with your group and group facilitator.

What *types* of actions can managers take to support the natural resilience of coral reefs (there are at least six)?

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2. Mechanics of a resilience assessment, prioritizing and targeting actions

Instructions: Review the matrix and map (see upcoming pages) and listen to your group facilitator's description of this portion of the activity, then answer these questions.

Questions:

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

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

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

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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?

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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?

____
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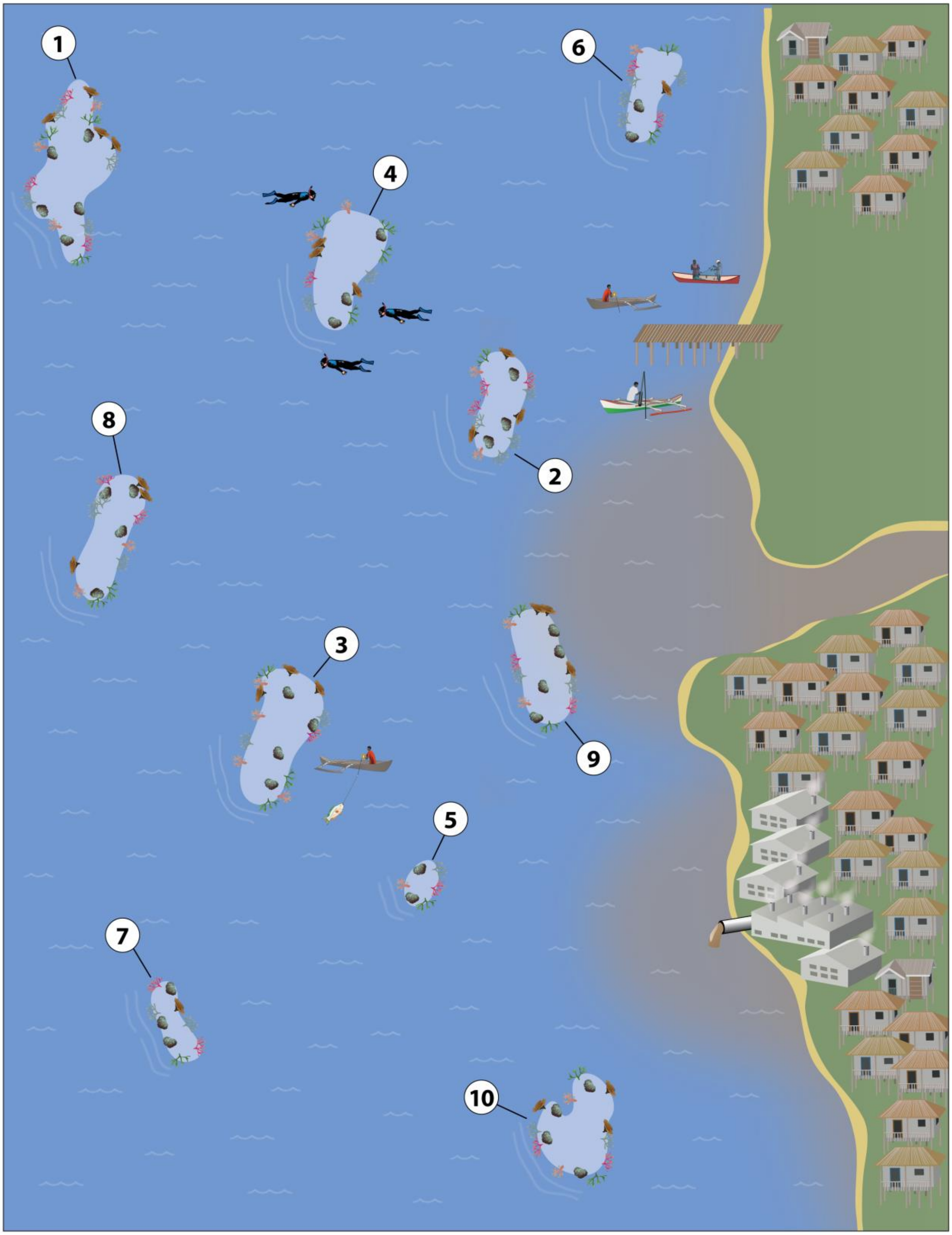
____

	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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Managing for Reef Resilience: Background Information

This section provides background on effective management and management strategies that can be used to help managers address local, regional, and global threats to support coral reef resilience.

Effective management includes the following components:

- Reducing stresses that may affect coral community health (e.g., over-fishing, pollution, agricultural and urban waste, silt, and sewage, etc.) will provide communities with a greater chance to survive bleaching stress or other major disturbances.
- Preventing damage is particularly important during times of stress, such as during a bleaching event. Preventing damage is critical because corals are more vulnerable to disease and other threats during these times.
- Enhancing Recovery for coral communities that have been impacted may include direct management interventions, like invasive algae removal or herbivore enhancement and fisheries management.
- Monitoring MPAs against baseline data and comparing MPAs to control reefs outside MPA boundaries is one of the best means of assessing the effectiveness of management strategies.
- Using Adaptive Management to measure and test the effectiveness of strategies for the site/s will improve future strategies.
- Communicating between managers and stakeholders to gain support for current and future actions is critical to achieving management goals and objectives.

1. Fisheries Management

Balancing demands for fish resources with biodiversity conservation can be one of the biggest challenges for coral reef managers. Conventionally, the influence of coral reef managers on fisheries activities was generally limited to MPAs. Increasingly, however, reef users and managers are realizing the importance of ecosystem approaches to fisheries management. Collaborations between fishers, fishery managers and coral reef managers are helping to integrate resource management with biodiversity protection.

This section introduces a range of strategies and tools that can help reduce the pressures from fishing on coral reef ecosystems while also improving the sustainability of fish stocks. Familiarity with these strategies can help reef managers play an influential role in broader fisheries management decisions.

Fishery regulations

Most countries have regulations and laws to control fishing activity. Often, these have been developed with the primary goal of protecting sovereign fishing rights, partitioning resources among fishing sectors or optimizing fishing yields. Increasingly, fishery managers, other policymakers and fishers themselves are calling for better controls that can improve the economic and ecological sustainability of fisheries. In many cases, this can provide an opportunity for coral reef managers to engage in review of conventional fishery controls, such as catch quotas, species bans, size restrictions, gear restrictions and area closures.

Protecting functional groups
In recent years, there have been exciting developments in fisheries management that have focused on protecting key functional groups, such as sharks and herbivores. Whether motivated by economic considerations (such as protecting sharks to support dive tourism) or ecological concerns (bans on catching herbivorous fishes to minimize risk of algae taking over reefs), these measures can make big contributions to reef resilience.

Compliance and enforcement
In many instances coral reef managers may find that unsustainability of fishing activities is due less to lack of regulation, and more to poor compliance. This is best addressed through a multi-faceted and collaborative approach that includes strengthened enforcement capacity, education of fishers and managers, and programs to reduce dependency on fishery resources (alternative livelihoods, supplemental incomes, alternative fishing resources, etc).

Reduce by-catch
The incidental catch of non-target species or undersized animals during fishing operations can have significant impacts on coral reef biodiversity. Sea turtles, sharks, seabirds and habitat-forming species such as sponges and sea fans are all the bycatch of fisheries. In many fisheries, juveniles of target species can be a significant portion of the bycatch. Coral reef managers can work with fishery managers to promote adoption of measures such as specialized bycatch reduction devices (such as turtle exclusion devices), use of selective fishing gear (larger hook size, or hook and line rather than nets), by-catch reporting and fishery observer programs.

Best practice and market-based incentives
An increasing number of fishing sectors are demonstrating social and environmental responsibility through adopting codes of conduct, fishery standards or stewardship programs. The U.N. Food and Agriculture Organization (FAO) has developed a Code of Conduct for Responsible Fisheries that includes a set of management practices to support sustainable fisheries. The aquarium collecting sector, through the Marine Aquarium Council, has developed its own standards for best practice, including a certification program. The Marine Stewardship Council's fishery certification program and seafood eco label aim to recognize and award sustainable fishing. A key ingredient for effective uptake of best practice is market demand, and these programs aim to also create a market for sustainable marine resources through informing consumer choice.

Protecting spawning aggregations
Protection of spawning aggregations is important for both fisheries management and biodiversity conservation. Spatial or temporal closures can be used to prevent fishing of aggregations or protect fish using migratory corridors. Effective protection of fish spawning aggregations can be a major contribution to resilience of targeted fish populations migrations if done in combination with other fishery management measures, such as size restrictions or

permitting. Science and Conservation of Fish Aggregations has resources to support efforts to protect fish aggregations.

Marine protected areas (MPAs)

MPAs can take many forms, but no-take areas are especially important for sustaining populations of targeted fish species. No-take MPAs can be established as tools for fishery management or for biodiversity protection, and often both objectives can be achieved simultaneously. MPAs are often thought of as formal arrangements enacted through government regulations. However, there is a long history of informal, local-scale marine management in many tropical cultures. A growing appreciation of the potential contribution of 'locally managed marine areas' (LMMAs) to regional conservation has seen rapid growth of formally recognized LMMAs.

Alternative livelihoods

Strong economic dependency on coral reef resources can be one of the most important causes of over-exploitation. As a result, coral reef managers and non-government organizations are increasingly working with local communities to identify and develop sources of income that help fishers to become less dependent on species that fished unsustainably, or that play important roles in ecosystem resilience.

Fishery reviews and Risk assessments

Regulated or permitted fisheries often have scheduled reviews of management arrangements. Ecological risk assessments are sometimes a requirement of a new fishery, or for fisheries wishing to meet new standards under ecosystem-based management approaches. These represent important opportunities for coral reef managers to work with the fishing sector to improve controls on a fishery and improve sustainability.

2. Local Interventions

While many of the most serious threats to coral reef ecosystems require action at national (i.e. fisheries) and international (i.e. climate change) levels, there are also a range of threats that can be tackled through local management interventions. Local management interventions can be an important component in a strategic approach to building reef resilience. By protecting high-value sites, they can support the viability of local communities and valuable reef-based industries. Local interventions can also produce benefits to the broader ecosystem if they are targeted at sites that are important for system resilience, such as important sources of coral larvae or critical fish breeding areas.

Local management interventions can be expensive or time-consuming to implement, but often are crucial considerations for the protection of small, high-value reef areas. Many will involve increased restrictions on the types or extent of use (such as area closures or restrictions on certain activities), and therefore will benefit from active engagement with reef users and local communities to build understanding and support (and therefore compliance) for management initiatives. Local management interventions can also be valuable ways to include stakeholders in efforts to protect reefs, offering opportunities to strengthen local stewardship in support of shared conservation goals.

The key types of interventions that can be important options for local management of high-value sites include:

- **Temporary closures**. During times of high stress, such as a bleaching event, managers can help minimize the severity of damage at important reef sites by protecting corals from activities that might exacerbate the effects of environmental pressures.
- **Control of coral predators.** Under certain conditions, natural coral predators (such as Crown-of-thorns starfish and *Drupella* snails) can reach outbreak densities and cause severe damage to reefs. Control of predators can be feasible for small, important reef areas.
- **Managing risks from invasives.** Invasive species can pose serious risks to coral reef ecosystems and managers should work with relevant partners to prevent, detect and control invasive species.
- **Managing recreational use of reefs**. Recreation is an important use of coral reefs, and one that can be managed to ensure sustainability of economic and social benefits, as well as enduring conservation outcomes.
- **Sea urchin management.** Sea urchins play important roles in coral reefs. Depending on circumstances, managers may wish to reduce urchin densities or enhance them to help restore balance to the ecosystem.
- **Mangaging watershed threats.** Appropriate land-use practices at high value sites are critical to ensure that the transport of sediment, nutrients and other pollutants to coral reefs is minimized.

Coral reefs are vulnerable to a range of acute disturbances that can have rapid onset and severe impacts, including vessel groundings, outbreaks of disease and coral predators, tropical storms and coral bleaching events. While these incidents vary in their spatial scale and the extent to which human activities are their cause, they can all require some level of response by coral reef managers.

While individual incidents can be inherently unpredictable, they are largely unavoidable. They can be visually dramatic, ecologically devastating and often attract significant public interest. Coral reef managers will inevitably need to respond to incidents in some way, and being prepared through incident response planning can be crucial for managing both environmental and reputational risk. Incident response plans can give managers the knowledge, tools and mandate to affect an appropriate response to these risks.

An effective response generally requires an appropriate organizational/policy mandate as well as the necessary operational capacity. Incident response plans can take varied forms, but the most common elements include:

- **Early warning –** a system for detecting when conditions are approaching stressful thresholds or detection of the early symptoms of stress is crucial to a timely response. More observers generally increase the likelihood that an incident can be detected early, so strategies for broad participation in early warning programs (such as volunteer programs) can be key to their effectiveness.

- **Response Management –** experts or experienced managers need to evaluate observations and reports from the early warning system to decide the need and scale of response. For each type of incident the response plan needs to define how the response will be managed, including response triggers, types of response, incident control system, communication strategy criteria for declaring when an incident response is over and post-incident monitoring and management.
- **Field Response –** an effective and efficient field response requires a standard operations procedure, which includes a mobilization protocol, team composition, equipment requirements, assessment methods, reporting procedures and communications protocols.
- **Management actions-** Management strategies in response to an incident will vary depending on the type and severity of the event. Implementation of management actions will be determined on a case-by-case basis, and factors such as extent and cause of the incident, feasibility of mitigation efforts, socioeconomic value of the reef, presence of rare or endangered species, the timing of the event will all be important in designing the responsive management actions.
- **Follow-up monitoring-** this is an important component of incident response, as it provides increased understanding of the long-term impacts to reefs from events and allows managers to evaluate the effectiveness of response actions.

See the tab on Preparing for and Responding to Bleaching Events in this Training Guide for guidance and resources on the design and implementation of incident response plans.

3. Ecological Restoration

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, or destroyed. The primary aim of coral reef restoration is to improve a degraded reef in terms of ecosystem structure and function. Other attributes of the system that may be considered for restoration include: biodiversity, habitat complexity, species biomass and productivity.

Restoration can involve passive or active interventions. Passive interventions usually involve removing anthropogenic stressors that are impeding natural recovery. Active restoration involves physical restoration and/or ecological restoration (e.g., transplantation of corals and other biota to degraded areas).

Coral reefs are highly complex systems: functioning reefs cannot be created by restoration interventions. However, there are cases where restoration can assist reef recovery through well-planned and managed interventions, developed with realistic expectations and appropriate investment and follow-through. Restoration may be a justifiable investment at small scales where a reef has been damaged through acute impacts - especially physical impacts - from human activities. Vessel groundings are a good example of the type of impact that has been managed in part through direct restoration of specific sites. Where chronic stressors (such as pollution) have contributed to reef degradation, direct restoration measures are unlikely to meet expectations.

Active restoration may also be warranted at larger scales where there is a need to accelerate biological processes of recovery, such as when there is widespread depletion of a population through selective mortality. The decline of *Acropora* populations in areas of the Caribbean due to disease is an example of a situation that has led managers to develop restoration strategies. These strategies have generally aimed to increase the density of reproductive individuals, rather than rebuilding reefs, one coral transplant at a time. Restoration can also be implemented to reinstate key ecological functions to a damaged reef. An example of this use of restoration is the enhancement of sea urchin populations to support algal control efforts in areas where seaweeds are preventing coral recovery.

Key considerations for coral reef restoration

- Coral reefs that are relatively unstressed by anthropogenic impacts can often recover naturally from disturbances without human intervention.
- Active restoration is not a magic bullet. Improved management of reef areas is the key.
- Targets or measurable indicators should be set that allow both the progress towards restoration goals to be assessed over time and adaptive management of the restoration project.
- Consider restoration as an ongoing process over a time-scale of years which is likely to need adaptive management, not as a one-off event.
- Active coral reef restoration has been carried out with some success at scales of up to a few hectares only.

Restoration can be a challenging area for coral reef managers due to the complexity of social, political, economic and ecological issues that need to be navigated. Fortunately, there is guidance tailored specifically for those interested in coral reef restoration. Managers should look at the GEF Coral Reef Targeted Research & Capacity Building for Management Program: http://www.gefcoral.org/.

Resilient MPA Design

This tab focuses on applying the resilience principles to MPA and MPA network design, or in the case of existing protected areas and networks, applying zoning. 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.

Table of Contents

Resilient MPA Design: Training Guidance

Estimated Time
45 minutes – Powerpoint Presentation
120 minutes - Group Activity
30 minutes – Poster session

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

Activity Description
1. Give Powerpoint Presentation: Resilient MPA Design (45 minutes)

2. Conduct MPA Design: Reef Classification Activity Part 1 (60 minutes)

Purpose: To develop a classification map of the major reefs types and zones for your region. 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:
- Delineate major reef types (e.g., atolls, barrier, fringing, patch) and zones (e.g., fore reef, back reef, spur and groove) on your map
- Identify three factors that explain major coarse divisions in coral reef communities across your region (e.g., wave energy, ocean circulation, isolation)
- Identify three factors that explain finer level differences (e.g., depth, salinity, turbidity)
- Apply these factors to differentiate among the reef types and zones on your map
- 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** so that you may return to this activity in the future.

Output: Country map with reef areas classified

Note to the Instructor:

- 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/exposes areas are, where you find strong currents. Then ask them what types of habitats they find in those locations.
- 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.

3. Conduct MPA Design: Zoning Activity Part 2 (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** so that you may return to this activity in the future.

- Review criteria below to further describe your area and identify critical areas
    - 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

- 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

- 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

4. Conduct Poster Session (Groups circulate around the room visiting other groups, asking questions, providing feedback on the map classifications and zoning)

Notes to the Instructor/Additional Resources

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.
- 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 http://www.coralcoe.org.au/events/webseminar/iyorvideos/terryhughes.html

Materials Needed

- Powerpoint Presentation: Resilient MPA Design (Flash drive)
- Large map for each geography represented (larger than 15x20 – bigger is better) – options: create standardized map for all groups or ask participants to bring these
- Acetate 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 20x20
- Dry-erase markers (5 colors minimum) 1 pack per group
- Dry eraser and/or paper towels
- Tape & scissors
- Notepad and pen to record decisions made during activity
- Rules of Thumb Checklist Handout (1 per group)

Handout: 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

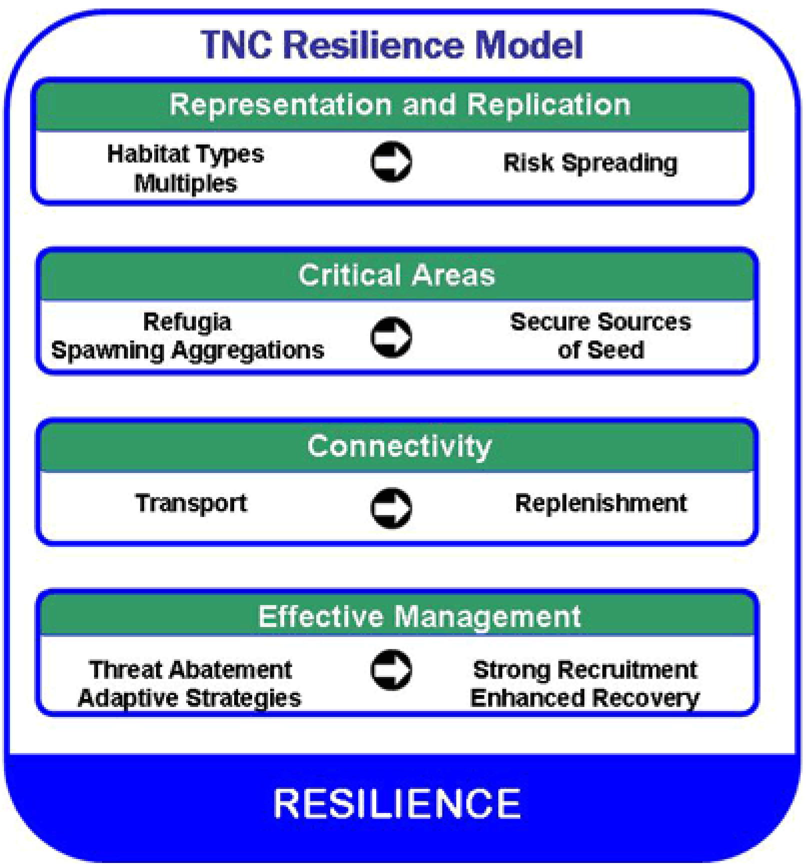
Resilient MPA Design: Background Information

This section helps coral reef managers to identify the resilience potential of sites relative to other sites locally to inform the design and management of MPAs and MPA networks.

Management strategies, such as MPAs, are likely to be most effective if they are implemented as part of an ecosystem-based approach to management. Ecosystem-based management considers the entire ecosystem (including humans) and aims to maintain healthy, productive and resilient ecosystems so they can provide the ecosystem services humans require. Well designed and effectively managed MPAs are a critical component of ecosystem-based management because they play a significant role in achieving sustainable use of marine resources at multiple scales.

1. TNC Resilience Model

The following Resilience Model has been developed to help conservation planners and managers build resilience into MPA design and management. The model was designed to specifically focus on ensuring coral reefs and associated habitats are resilient in the face of climate change (Salm et al. 2006; Mcleod et al. 2009).



The model is composed of four principles:
Principle 1: Representation and Replication (and risk-spreading) can help increase the likelihood of reef survival. Since species vary with habitat type, it is important to represent at least 20-30% of each habitat (each type of coral reef and associated habitats like mangrove forests and seagrass beds) in no-take areas. Because climate change and other stressors will not impact marine species and habitats equally everywhere, strategies for spreading the risk must be built into MPA network design. To spread the risk of losing one habitat type in a bleaching event or other natural disaster, managers should protect multiple examples (replicates) of the full range of marine habitat types, spread them out to minimize the chance that they will all be wiped out by the same disturbance, and include at least 3 examples of each habitat type in MPA networks.

Principle 2: Critical Areas provide secure and essential sources of larvae to enhance replenishment and recovery of reefs damaged by bleaching, hurricanes or other events. They include high-priority conservation targets, such as areas that are naturally more resilient to coral bleaching, fish spawning aggregations and nursery habitats, and turtle nesting areas.

Principle 3: Connectivity refers to the natural linkage between marine habitats (Roberts et al. 2003)], which occurs via larval dispersal and the movements of adults and juvenile, and is an important part of ensuring larval exchange and the replenishment of biodiversity in areas damaged by natural or human-related impacts. Consequently, it is important that biological patterns of connectivity among reefs be identified and incorporated into MPA network design. Preserving connectivity within and among reefs and their associated habitats ensures replenishment of coral communities and fish stocks from nearby healthy reefs following disturbance, and enhances recovery.

Principle 4: Effective Management is essential to meeting the goals and objectives of an MPA. Reducing threats is the foundation for successful conservation and the core of resilience-based strategies. Effective management describes both daily activities taken by resources managers to reduce threats to reefs as well as long-term, community-based efforts that work to support and enhance ecosystem function and resilience. Such long-term efforts include managing ecological processes (e.g., herbivory). For example, fished reefs are more likely to degrade rapidly due to the overharvest of herbivorous fishes. This can result in macroalgae outcompeting corals in response to reduced fish grazing (Mumby and Steneck 2008). Evaluating management effectiveness provides the foundation for adaptive management. Investments in human capacity and long-term financing are also crucial to sustaining effective management for the future.

The TNC Resilience Model is designed to emphasize the key aspects of managing MPAs 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 in an area. The most effective MPA configuration is a network of highly protected areas nested within a broader management framework. Such a framework might include a vast multiple-use reserve managed for sustainable fisheries as well as protection of biodiversity. The ideal MPA system would be integrated with coastal management regimes to enable effective control of threats originating upstream, and to maintain high water quality (Done and Reichelt 1998).

2. Resilient MPA Design

The design of MPAs for resilience or a network of resilient MPAs encompasses cross-disciplinary considerations contributing to how management decisions are ultimately made and implemented. The biophysical design principles presented in this section are only one part of the process of establishing MPA networks. Socioeconomic, political and governance issues are equally important parts of the process.

Five criteria help coral reef managers and practitioners plan and design resilient MPAs and MPA networks:

- Protect multiple examples of the full range of coral habitat types.
- Ensure critical areas are incorporated into the MPA design.
- Incorporate connectivity through size, shape and spacing of MPAs.
- Identify and accommodate for the social relationships, dynamics, cultural traditions, values and socioeconomic aspects of the MPA and area adjacent to the MPA.
- Provide effective management of marine resources to achieve fisheries, biodiversity and climate change objectives, which requires careful application of a wide range of tools and methods.

The following sections explain these criteria and provide specific design principles intended to help managers plan and manage their MPAs and/or networks. Biophysical principles are provided to help MPA networks achieve multiple objectives, including fisheries sustainability, biodiversity conservation and ecosystem resilience in the face of climate change and other stressors. These principles can be applied to MPA network design at any scale.

2.1. Representation and Replication

Representation

The representation criterion of MPA design seeks to achieve protection of the full range of habitats and communities within the region, through adequate representation and replication of key habitats (described below). MPAs that include representation of habitats and communities in a well-connected network are more likely to persist and be resilient in response to climate changes.

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. When assessing representation for MPA network design, three 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, geographic and environmental gradients in habitats and species composition.

- Ecosystem integrity: maintenance of the ecological processes of the system is as important as representing all habitat.

Design Principles

- Ensure 20-40 percent of each habitat is represented within no-take areas.
- Represent the range of types of coral reefs, seagrass, mudflats, algal beds, soft seabed communities, rocky shores, coastal forests, beaches, mangroves, other wetlands and other habitats in no-take areas. Representing the range of habitats is similar to taking a system-wide approach to designing a network of marine protected areas – which is consistent with taking an ecosystem approach to fisheries management.
- If the only protection offered is no-take areas, then the proportion of no-take areas needs to be higher (30-40 percent); if additional effective protection is in place (e.g., fishing restrictions) or if fishing pressure is low, then apply 20 percent to no-take areas.
- Have a mixture of protected area boundaries: both within habitats and at habitat edges.
- MPA boundaries that are located at habitat edges (e.g. at the edge of coral reefs) are recommended for achieving biodiversity, climate change and some fisheries production by minimizing spillover of adult fished species. Matching the edge of an MPA with a habitat boundary (e.g., reef edge) can enhance conservation benefits for mobile species by limiting spillover into non-protected areas. Conversely, to encourage fisheries benefits, MPA some boundaries should be in the middle of fish habitats to allow spillover of adult species to non-protected, fished areas. Adult spillover can be enhanced if individual fish traveling through the same habitat move from protected to non-protected areas.

Replication

Replication is the inclusion of multiple samples of habitat types in MPAs and networks to spread the risk of coral reef damage from 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 can support 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.

Replicate MPAs also enable the dispersal of marine species between areas. Many marine species 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 population exchange role of MPAs. Include at least three widely-separated replicates of every habitat within a protected area network, ideally, in no-take areas.

2.2. Critical Areas

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 necessary to replenish damaged areas. Protection of areas that are known to be resistant or resilient to threats, including climate-related or other local stressors, is important. This section highlights the importance of considering special biological and ecological elements of a coral reef system.

The following biologically and ecologically significant areas provide important ecosystem functions and should be considered for inclusion in MPA design:

- Sources of larvae and spawning aggregations.
- Nursery and breeding grounds of fish and other marine organisms can be vital sources of larvae for other areas. Protection of important sources of reproduction (e.g., nurseries and breeding grounds), and protection of areas that will receive recruits and be future sources of spawning potential, are important targets for self-sustaining MPAs.

Source areas functioning as a refuge from fishing for individuals of certain species lead to an increase in the number of larger, older individuals who carry a more important role for reproduction in the community, and can also potentially act as sources of propagules for other areas.

- Developmental and feeding habitats and other key habitats at certain life stages for species play an important role in ecosystem functions and require consideration in the MPA design.
- Migration corridors.
- Habitats for rare or threatened species (e.g. turtle nesting areas) are particularly at risk. Inclusion of these sites within the network can help ensure all examples of the biodiversity and processes of the ecosystem are protected.
- Areas that may naturally be more resistant or resilient to climate change.

Design Principles

- Ensure that no-take areas include critical habitats.
- Include important aggregation sites (e.g., spawning, feeding, breeding grounds), juvenile fish habitat areas, and larval sources.
- Include special or unique sites in the MPA network.
- Protected areas should include sites that are important for: rare or threatened species (e.g. turtle nesting sites); rare or threatened habitats; highly biodiverse and those at risk; endemic species or habitats and isolated sites.
- Include resilient sites in the MPA network.
- Protected areas should include areas that are more likely to survive climate change impacts as indicated by either previous survival or conditions that make them more likely to resist, or recover from impacts.
- 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 of known sensitive or unique areas.

2.3. Connectivity

Connectivity refers to the extent to which populations are linked by the exchange of eggs, larval recruits, juveniles or adults. It also refers to the ecological linkages associated with adjacent and distant habitats. Connectivity within and between protected areas is important for maintaining diversity, fish stocks, and especially important for maintaining ecosystem resilience.

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

- Connections of linked 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 another.
- Marine life adult movements in their home range, from one site to another, or because of spillover effects.

Connectivity and Ecological Processes

Connectivity is important for supporting ecological processes (e.g., herbivory) that promote reef resilience. For example, connectivity between coral reefs and mangroves can increase grazing on adjacent reefs. Herbivorous fish remove algae and therefore can promote coral growth and reef resilience. Mangroves in the Caribbean have been shown to increase the resilience of offshore coral reefs in response to disturbances such as hurricane damage. After a disturbance event on a reef, macroalgae may out-compete corals for space, so maintaining healthy populations of fish that eat algae is critical for coral reef recovery. Mangroves support increased biomass of fish that eat macroalgae; thus, connectivity between mangroves and reefs can help corals recover from disturbance and enhance their rates of recovery.

Recent studies discuss the importance of incorporating connectivity into conservation planning. These studies demonstrate how ecological processes (e.g., connectivity among habitats) can be integrated into decision support tools such as reserve selection algorithms (e.g., MARXAN) to help improve the performance of protected areas. Such efforts are important to help managers integrate ecosystem-based management into the design of marine protected areas.

Design Principles

<u>SIZE</u>

- Apply minimum and a variety of sizes to protected areas within the network.
- Using networks of protected areas is one way to increase connectivity between sites without matching the size of each site with adult and larval movement patterns. MPA size

will depend on the MPA objectives, the movement patterns of key species of importance, and if other management strategies are in place.

- For no-take areas: If no additional effective protection is in place (e.g., no fisheries input/output controls for wide ranging species), a mixture of small (a minimum of 0.4 km2 or 40 ha) and large (e.g,. 4 to 20 km across) no-take areas is recommended. If there is additional protection for wider ranging species, then networks of small no-take areas can achieve most objectives, particularly regarding fisheries management.
- For temporal closures of any kind: should be, at minimum, the entire area of site plus a 100 m buffer.
- For zones with gear restrictions: as large an area as possible, up to the entire marine managed area and all areas where gear interferes with threatened species.

<u>SPACING</u>

- Apply minimum and a variety of spacing distances between protected areas within the network.
- For no-take areas: Inshore no-take areas should be located closer together (≥1 km apart) than offshore no-take areas (~20 km apart).
- For temporal closures of any kind: Other types of protected areas (e.g., spatial gear or access restrictions) might be quite large in extent (e.g., throughout the management area), and so it may not make sense to have specified “distances” between them. However, if other permanent protected areas are isolated “islands” of protection, then the same spacing rules (and rationale) apply as no-take areas.

<u>SHAPE</u>

- Use square or circular shapes for MPAs subject to considerations of compliance (e.g. including using landmarks).
- Square and circles allow for limited adult spillover, which helps maintain the integrity of the protected areas and, therefore, the sustainability of their contribution to fisheries production, biodiversity and ecosystem resilience. Other shapes (e.g. long and thin) may facilitate more spillover to fished areas.
- Locate more protection upstream of currents, when known.
- If local information regarding biological patterns of connectivity is not available, and if currents are known and consistent, then a greater number of the protected areas (especially no-take areas) should be located towards the upstream end of the management area.

Linked Habitats

Ocean habitats are connected through transfer of nutrients and materials as well as the habitat utilization of juvenile and adult organisms. Demographic or ecological connectivity involves the extent of linkage that occurs among nearby local populations of a species due to the exchange of individuals. This type of connectivity is important for MPAs, when making decisions concerning design and management, and when trying to determine the optimum amount of reef habitat to protect.

The following adjacent habitat types should be considered in the design of the MPA network:

Reef Flats

Corals on reef flats and upper reef crests exposed at low tides often exhibit stress tolerance, and may resist or recover rapidly from bleaching. They will be important providers of larvae that may settle in dead areas and aid their recovery.

- Reef flats often provide vital nurseries for reef fishes that will move onto the reef and help reestablish communities affected by bleaching.
- Nitrogen and organic materials produced on reef flats, or transported from there in the form of feces of herbivorous fishes and other organisms, contribute valuable nutrients to the reef community. The transfer of materials aids in the overall functioning and recovery of the system.

Back-reef Lagoons

Coral assemblages in back-reef lagoons, especially shallow lagoons behind fringing reefs, are routinely exposed to wide temperature fluctuations. Consequently, the corals may exhibit some acclimatization to temperature stress and resistance to bleaching.

- Back-reef lagoons can serve as important nurseries for fish.
- Corals in naturally turbid, deeper lagoons may display higher resistance to bleaching than corals of the same species in clear waters over barrier reefs.

Seagrass Beds and Sand Flats

Seagrass beds and sand flats surrounding coral reefs are important feeding grounds for nocturnal feeding fishes, such as snappers and grunts, which take shelter on reefs by day. After feeding in the seagrass beds and sand flats, the fish return to the reef, and deposit nutrients (to the reef food web, and contribute to the growth and recovery of reef communities.

Mangroves

The generally turbid waters and shading effect of mangroves may reduce the susceptibility of adjacent corals to bleaching.

- When in close proximity to reefs, mangroves can provide feeding grounds to fishes that take shelter on the reefs.
- Mangroves introduce fixed nitrogen and organic detritus into the coral reef food chain, as do reef flats and seagrass beds.
- Mangroves can provide intermediate nursery habitat between seagrass beds and patch reefs that increase the survival of young fish, thus mangroves can strongly influence the community structure of fish on adjacent coral reefs.
- Research in the Caribbean demonstrated that the biomass of several commercially important fish species more than doubled when adult habitat was connected to mangroves, reinforcing the need to for conservation efforts to protect connected corridors of mangroves, seagrass beds and coral reefs. More recent studies in Australia also demonstrate that connectivity between reefs and mangroves in reserves promotes the abundance of harvested fish species.

Beaches and Dunes
Coastlines are dynamic zones. Disturbances to these areas can cause beach erosion, alteration of the natural cycle of accumulation and erosion of sand along the shore, increased turbidity of inshore waters, or even smother living reefs with excessive sediment.

Adjacent habitats contribute different types and quantities of larvae to reef systems, and may exhibit different susceptibility to bleaching. Therefore, it is important to identify these reefs and include multiple examples of each in the protected area, when possible.

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: swimming speed and directional capabilities of larvae are considered to be highly species-specific
- Larval duration: amount of time larvae spend in the open ocean is also species-specific; ranging from hours to months, and typical pelagic duration is 28-35 days
- Food resources: amount of available food during the pelagic duration
- Predators encountered: predators affect survival, condition and growth rates
- Influences of currents or other oceanographic factors
- Recent studies also show huge variability in larval dispersal distances, and lower dispersal distances than previously thought (e.g., 100m to 1km to 30km).

Some important conclusions can be drawn with respect to larval dispersal. The first is that connectivity among populations of reef species is primarily, or (for sessile species) exclusively, due to dispersal during larval life. Second, for the majority of reef species that have been studied, demographic connectivity has been shown to act on scales of up to tens of kilometers, rather than on scales of hundreds of kilometers or more. This local scale pattern of self-recruitment and connectivity among reefs has implications on the sizes required for MPAs within a network, and may indicate that even relatively small MPAs may be self-sustaining. Additionally, recent research on the Great Barrier Reef demonstrates that well protected marine reserve networks can make a significant contribution to the replenishment of fish populations both within the reserve and also on adjacent fished reefs.

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).

Adult movement is generally at a smaller scale than larval movement, and varies widely among species. Adult species movement patterns vary greatly. To protect a range of species within the MPA, a range of adult movement patterns needs to be considered in the MPA network design. If adults move widely, the ocean neighborhood is large and diffuse. If adults are sessile, then the ocean neighborhood might be small and distinct.

2.4. Socioeconomic Criteria

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. The creation of an MPA network with both socioeconomic and biophysical objectives 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.

Social and Economic Ecosystem Services

Social criteria to consider with MPA design include:

- Social acceptance (whether the local community supports the MPA)
- Recreation (degree to which an area could be used for recreation)
- Education and research opportunities
- Culture (religious, historical, cultural values of a site)
- Conflicts of interest (degree to which protection affects activities of local residents) etc.

Economic criteria to consider with MPA design include:

- Economic benefits (how protection will affect the local economy)
- Importance to fisheries (number of dependent fishers and size of yield)
- Importance to species (degree to which certain commercially important species depend on the area)

Design Principles

- When feasible, evaluate and measure the ecosystem services of the area
- 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

2.5. Effective MPA Management

Effective management refers to the daily activities required of managers as well as larger, community-wide efforts to address problems such as local pollution, poorly planned coastal development, and destructive fishing practices. Other sections in this training guide provide guidance on the design of resilient MPAs, but effective management of the ecosystem is critical for the full application of these design principles.

Effective management includes the following components:

- Reducing stresses that may affect coral community health (e.g., over-fishing, pollution, agricultural and urban waste, silt, and sewage, etc.) will provide communities with a greater chance to survive bleaching stress or other major disturbances.
- Preventing damage is particularly important during times of stress, such as during a bleaching event. Preventing damage is critical because corals are more vulnerable to disease and other threats during these times.
- Enhancing Recovery for coral communities that have been impacted may include direct management interventions, like invasive algae removal or herbivore enhancement and fisheries management.
- Monitoring MPAs against baseline data and comparing MPAs to control reefs outside MPA boundaries is one of the best means of assessing the effectiveness of management strategies.
- Using Adaptive Management to measure and test the effectiveness of strategies for the site/s will improve future strategies.
- Communicating between managers and stakeholders to gain support for current and future actions is critical to achieving management goals and objectives.

See tab on Managing for Reef Resilience for more information on managing for resilience.

Preparing for and Responding to Bleaching Events

This tab focuses on preparing and responding to bleaching events. It provides information on Early Warning Systems, monitoring bleaching events and guidance to develop incident response plans. Presentations and activities highlight important considerations in developing bleaching response plans and provide information on how to communicate to media, government and stakeholders.

Table of Contents

Preparing for and Responding to Bleaching Events: Training Guidance

Estimated Time
50 minutes – Powerpoint Presentation: Preparing for and Responding to Bleaching Events
(NOTE: The Powerpoint Presentation from Activity: Early Warning Systems (EWS) complements this powerpoint well. You may wish to consider using the EWS presentation to supplement this activity, or use it as a stand-alone activity.)
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 facilitator – can group students by geography
Full Session – Up to 25 students (absolute max is 30)

Learning Objectives
Possible learning objectives for this training: (depending on the scope of activities you use by the end of this training students will be able to:

- ✓ Understand why we need to assess the ecological impacts of mass coral bleaching.
- ✓ Identify bleached corals.
- ✓ Assess the geographic extent and severity of a mass bleaching event.
- ✓ Understand how bleaching assessments differ to normal monitoring.
- ✓ Be prepared to develop a bleaching response plan for their site.
- ✓ Understand the different types and scale of bleaching response plans used by managers globally
- ✓ Understand that managers can do something locally to respond to mass bleaching events
- ✓ Understand coral reef "triage" and restoration options available for MPA managers to implement in response to severe mass coral bleaching
- ✓ Understand a range of short-term, local strategies for coral bleaching management:
    - Area closures: visitor/fishing pressure reduction
    - Cooling waters: experimental induction of localized upwelling
    - Water circulation manipulations
    - Shading strategies
    - Sea surface condition manipulations
    - Minimize human-induced sedimentation impacts
    - Improve water quality

Activity Description

1. Give Powerpoint Presentation: Preparing for and Responding to Bleaching Events (50 minutes)

2. Facilitate a discussion about bleaching monitoring and response plans (20 minutes)

3. Optional: Conduct Activity: Developing a Bleaching Monitoring and Response Plan (2-3 hours)

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

   Instructions:
   - Divide group into smaller groups of 4-5 people, based on regions, and instruct them to work as a group or independently (as appropriate) through the Bleaching Monitoring and Response Plan worksheet.
   - Present the goal of the session to the group and give the groups the instructions.
   - In their groups they will develop a bleaching response plan for a coral reef area under your management (*i.e.*, the area managed by one group member).
   - They may use others as a resource, and solicit feedback from group members or facilitators as needed.
   - Note: If a current Bleaching or Integrated Response Plan exists for the site, the activity time can be used to revisit your plan and consider opportunities to integrate information you learned in the workshop to update the plan.

   Output: Draft Bleaching Monitoring and Response Plan

Notes to the Instructor/Additional Resources
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.

4. (Optional) Early Warning Systems Training Activity, if it is determined that the target audience could benefit from a more in depth understanding of and how they work it is suggested to use the Early Warning Systems Training Activity at this point. If you decide to use the EWS Training and Exercise it will extend the total activity time by 1:15 minutes).
5. (Optional) Report back to large group

Materials Needed
- Powerpoint Presentation: Preparing for and Responding to Bleaching Events (Flash drive)
- Powerpoint Presentation: Early Warning Systems (Optional) (Flash drive)
- Bleaching Monitoring and Response Plan Handout (Flash drive)
- Flip charts
- Markers

Early Warning Systems: Predicting Mass Coral Bleaching: Training Guidance

Note: This training activity can be used to supplement the Training Activity: Preparing and Responding to Bleaching Events if it is determined that the target audience could benefit from a more in depth understanding of Early Warning Systems and how they work.

Estimated Time
45 minutes – Powerpoint Presentation: Early Warning Systems: Predicting Mass Coral Bleaching
30 minutes – Activity: "You Make the Call"

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

Activity Description
1. Give Powerpoint Presentation: Early Warning Systems (45 minutes)

2. Activity: "You Make the Call" (30 minutes)

   Purpose: to integrate information from many sources to determine bleaching risk: weather, sea surface temperature, and local conditions. The activity simulates a three-week event.

   Instructions:
   - 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.

3. Discussion: Engage the full session in a discussion after the exercise (5 minutes)

Notes to the Instructor/Additional Resources

- 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 section down to the essential concepts that can be presented in about 45 minutes. This section is important in the Reef Resilience 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.

- NOAA Coral Reef Watch online tutorial: http://coralreefwatch.noaa.gov/satellite/education/tutorial/welcome.html
- **Alternative hands-on exercise:** could be done individually by students in the class, or by the instructor as a concept review before teaching: "A Classroom Activity Using Satellite Sea Surface Temperatures to Predict Coral Bleaching." Free download: http://www.tos.org/oceanography/archive/22-2_parker.html
- **Community-based program websites:**
  Florida Keys: http://isurus.mote.org/Keys/bleaching.phtml
  Western Indian Ocean: http://cordioea.net/bleachingalert/
  Mesoamerican Barrier Reef (Mexico, Belize, and Honduras): http://www.ecomarbelize.org/mar-coral-watch.html
  Hawaii: http://www.reefcheckhawaii.org/eyesofthereefBleach.htm

Materials Needed

- PowerPoint Presentation: Early Warning Systems (Flash drive)
- Flip charts and pens to record any discussion following the presentation
- Printout of scenarios for "You make the call" group activity (flash drive)

Handout: You Make the Call

Location 1: Lagoon reef, low tidal range, near river mouth.

Rate your location with “high,” “medium,” or “low” risk for bleaching.

Current Conditions Report: Week 1

Recent Weather:

Low wind, no clouds, warming

Satellite Bleaching Alert Status: Bleaching Watch

-- Bleaching Degree Heating Weeks : 0.0 Deg C-week
-- Coral bleaching HotSpot : 0.5 Deg C
-- Sea surface temperature : 28.5 Deg C

Bleaching observations: No bleaching

Other events: None

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 2

Recent Weather:

Low wind, increasing clouds, warming

Satellite Bleaching Alert Status: Bleaching Warning

-- Bleaching Degree Heating Weeks : 1.5 Deg C-week
-- Coral bleaching HotSpot : 1.5 Deg C
-- Sea surface temperature : 29.5 Deg C

Bleaching observations: Minor bleaching

Other events: None

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 3

Recent Weather:
Heavy rain, cloudy, warming

Satellite Bleaching Alert Status: Bleaching Warning

-- Bleaching Degree Heating Weeks : 3.5 Deg C-week
-- Coral bleaching HotSpot : 2.0 Deg C
-- Sea surface temperature : 30.0 Deg C

Bleaching observations: Moderate bleaching

Other events: Heavy rain causes flooding, increases turbidity.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:______________________________________

Location 2: Channel reef, low tidal range, near active dredging site.

Rate your location with “high,” “medium,” or “low” risk for bleaching.

Current Conditions Report: Week 1

Recent Weather:

Low wind, partly cloudy, warming

Satellite Bleaching Alert Status: No Stress

-- Bleaching Degree Heating Weeks : 0.0 Deg C-week
-- Coral bleaching HotSpot : 0.0 Deg C
-- Sea surface temperature : 28.6 Deg C

Bleaching observations: Minor bleaching

Other events: None

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 2

Recent Weather:

Low wind, no clouds, warming

Satellite Bleaching Alert Status: Bleaching Warning

-- Bleaching Degree Heating Weeks : 1.0 Deg C-week
-- Coral bleaching HotSpot : 1.0 Deg C
-- Sea surface temperature : 30.1 Deg C

Bleaching observations: Moderate bleaching

Other events: Dredging moderately impacts water quality.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 3

Recent Weather:

Moderate wind, increasing clouds, warming

Satellite Bleaching Alert Status: Bleaching Warning

-- Bleaching Degree Heating Weeks : 3.5 Deg C-week

-- Coral bleaching HotSpot : 2.5 Deg C

-- Sea surface temperature : 31.6 Deg C

Bleaching observations: Severe bleaching

Other events: Dredging heavily impacts water quality.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Location 3: Lagoon reef, high tidal range, popular snorkelling site.

Rate your location with “high,” “medium,” or “low” risk for bleaching.

Current Conditions Report: Week 1

Recent Weather:

Moderate wind, partly cloudy, cooling

Satellite Bleaching Alert Status: Bleaching Watch

- -- Bleaching Degree Heating Weeks : 0.5 Deg C-week
- -- Coral bleaching HotSpot : 0.5 Deg C
- -- Sea surface temperature : 29.8 Deg C

Bleaching observations: Minor bleaching

Other events: New moon, spring tides.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:____

Current Conditions Report: Week 2

Recent Weather:

Low wind, no clouds, warming

Satellite Bleaching Alert Status: Bleaching Warning

- -- Bleaching Degree Heating Weeks : 2.5 Deg C-week
- -- Coral bleaching HotSpot : 2.0 Deg C
- -- Sea surface temperature : 31.3 Deg C

Bleaching observations: Moderate bleaching

Other events: Neap tides.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:____

Current Conditions Report: Week 3

Recent Weather:
Low wind, increasing clouds, warming

Satellite Bleaching Alert Status: Bleaching Alert Level 1
-- Bleaching Degree Heating Weeks : 5.0 Deg C-week
-- Coral bleaching HotSpot : 2.5 Deg C
-- Sea surface temperature : 31.8 Deg C

Bleaching observations: Moderate bleaching

Other events: Full moon, spring tides.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Location 4: Backreef, high tidal range, marine protected area.

Rate your location with “high,” “medium,” or “low” risk for bleaching.

Current Conditions Report: Week 1

Recent Weather:

Moderate wind, partly cloudy, cooling

Satellite Bleaching Alert Status: Bleaching Warning

-- Bleaching Degree Heating Weeks : 3.0 Deg C-week
-- Coral bleaching HotSpot : 3.0 Deg C
-- Sea surface temperature : 32.3 Deg C

Bleaching observations: Moderate bleaching

Other events: None.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 2

Recent Weather:

Low wind, no clouds, cooling

Satellite Bleaching Alert Status: Bleaching Alert Level 1

-- Bleaching Degree Heating Weeks : 4.0 Deg C-week
-- Coral bleaching HotSpot : 1.0 Deg C
-- Sea surface temperature : 30.3 Deg C

Bleaching observations: Severe bleaching

Other events: None.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:_______________________________________

Current Conditions Report: Week 3

Recent Weather:
Strong winds, heavy rain, cloudy, cooling

Satellite Bleaching Alert Status: No Stress
-- Bleaching Degree Heating Weeks : 4.0 Deg C-week
-- Coral bleaching HotSpot : 0.0 Deg C
-- Sea surface temperature : 25.3 Deg C

Bleaching observations: Moderate bleaching

Other events: Category 4 Cyclone Bruce passes 50 km to the east.

Threat rating: Based on current weather and bleaching observations, the threat of widespread coral bleaching is rated as:______________________________________

Preparing and Responding to Bleaching Events: Background Information

1. Climate Change: Coral Bleaching

For information see tab on Climate Change: Key Issues for Coral Reefs, Bleaching

2. Bleaching Impacts

Coral bleaching and associated mortality not only have negative impacts on coral communities, but they also impact fish communities and the human communities that depend on coral reefs and associated fisheries for livelihoods and wellbeing.

Ecological impacts of coral bleaching and related mortality include:

- Bleached corals are likely to experience reduced growth rates, decreased reproductive capacity, increased susceptibility to diseases and elevated mortality rates.
- Changes in coral community composition can occur when more susceptible species are killed by bleaching events.
- Changes in coral communities also affect the species that depend on them, such as the fish and invertebrates that rely on live coral for food, shelter, or recruitment habitat. Change in the abundance and composition of reef fish assemblages may occur when corals die as a result of coral bleaching.
- Declines in genetic and species diversity may occur when corals die as a result of bleaching.

Socioeconomic impacts of coral bleaching and related mortality include:

- Degraded coral reefs are less able to provide the ecosystem services on which local human communities depend. For example, degraded reefs are less productive and may not be able to sustain accretion rates necessary to ensure reefs continue to provide shoreline protection services.
- Reefs damaged by coral bleaching can quickly lose many of the features that underpin the aesthetic appeal that is fundamental to reef tourism. The resultant loss of revenue from reduced tourist activity can threaten the livelihoods of local communities.
- Coral bleaching events that lead to significant coral mortality can drive large shifts in fish communities. This can translate into reduced catches for fishers targeting reef fish species, which in turn leads to impacts on food supply and associated economic activities.
- Cultural values of many tropical island communities (e.g., religious sites and traditional uses of marine resources) depend upon healthy coral reef ecosystems and can be adversely affected by coral bleaching.
- Coral reefs are a valuable source of pharmaceutical compounds. Degraded and dead reefs are less likely to serve as a source for important medicinal resources (i.e., drugs to treat heart disease, cancer, and other illnesses).

Bleaching Impacts on Fish Communities
Nearly everything in a coral-reef ecosystem depends on corals, or on the reef structure in some way. Coral colonies provide a source of food and shelter for countless reef-associated organisms and their health is of critical importance to the ecology of the reef community. Scientists are discovering that the ecological impacts of coral decline can have detrimental effects on fish communities. For example, a study in Papua New Guinea (Jones et al. 2004) showed a decline in fish communities following declines in associated coral communities. Additionally, the study suggested that juvenile fish are more likely to recruit to areas that have high coral cover. Similar results of declines in fish populations following extensive coral bleaching have also been observed in other areas, such as the Great Barrier Reef (Booth and Beretta 2002), Tanzania (Garpe et al. 2006) and the Seychelles (Graham et al. 2006). Phase shifts in fish species have also been documented (e.g., from dominance of coral-associated fish species to less habitat-specific fish species) following a bleaching event (Bellwood et al. 2006).

Bleaching Impacts on Human Communities
Degradation of coral reefs also greatly affects human communities that rely on them. People rely on reefs for food, income, and enjoyment. Many hundreds of millions of people are dependent in some way on the goods and services provided by coral reefs, with over 100 million directly dependent on coral reefs for their survival.

Attempts to put dollar values on the global costs of coral bleaching suggest that reef degradation from bleaching could cost from $20 billion (moderate bleaching) to over $84 billion (severe bleaching) in Net Present Value (over a 50-year time horizon). The losses to tourism are highest ($10 billion - $40 billion losses), followed by fisheries ($7.0 billion - $23.0 billion), and biodiversity ($6 billion - $22 billion) (Cesar et al. 2003).

3. Resistance, Tolerance and Recovery
If a coral reef is exposed to stressful conditions that are known to cause bleaching, its fate is influenced by three key ecological attributes: the extent to which corals can withstand elevated stress without bleaching (resistance), the ability of corals to survive bleaching (tolerance), and the ability of coral communities to be replenished (recovery) should significant coral mortality occur. An understanding of these attributes and the factors that influence them can inform management responses that aim to maximize the resilience of reefs to climate change.

Resistance
The variability that characterizes bleaching events points to an important fact: individual corals vary in their bleaching responses to light and heat stress. Variability in the severity of bleaching response has been observed within individual coral colonies, among colonies of the same species, and across different species. These taxonomic variations are further compounded by spatial patterns, with corals of the same species often showing different bleaching responses at different locations. These patterns have been observed at scales ranging from meters to thousands of kilometers. Some of the factors that influence the coral response include:

- Sea-surface temperature patterns, especially at large scales
- Regional and local differences in weather

- Proximity to upwelling of cooler water
- Water currents and flow regimes
- Genetic identity of corals
- Genetic variation in zooxanthellae
- Severity of local stressors due to human activities

Tolerance
For those that survive a bleaching event, characteristics that influence a return to a healthy coral reef community include:

- Severity of bleaching event: The severity of a bleaching event affects whether a coral loses zooxanthellae in response to thermal stress and also affects the amount of zooxanthellae lost.
- Immune system response: A weakened immune system is less capable of fighting off disease. Because coral reefs are weakened by a bleaching event, their ability to reproduce and fight diseases may be impaired.
- Metabolic adaptations: Persistence of these coral reefs may depend in part on the differential ability of some corals to acclimatize warmer temperatures.

Recovery
Reefs that suffer substantial mortality face different challenges than those where the majority of corals manage to survive the bleaching event. The biggest difference is the need for a much longer time period until returning to pre-bleaching structure. How long it takes a coral community to recover from bleaching related mortality depends on a variety of factors, including:

- Favorable recruitment conditions: These include good water quality, open hard substrate for settlement, presence of coralline algae (provide settlement substrate and chemical cues to facilitate coral settlement), and healthy herbivore populations**.**
- Larval supply: Regardless of how good recruitment conditions are (e.g., availability of substrate, presences of important herbivores), reefs require a robust supply of larvae from source reefs to recover following a disturbance event.
- Connectivity: Reefs with high mortality after bleaching depend on connectivity to other sources of live corals for re-seeding. For example, it is possible for reefs receiving great numbers of larvae from other source reefs to recover in a relatively short time span (~10 years), provided that recruitment conditions are favorable.
- Grazing: If important herbivores are missing, overgrowth by algae can slow reef recovery by taking up space that would otherwise be available to coral recruits.
- Natural selection: The recovery of coral reefs may be facilitated by settlement of larvae from nearby, more heat-resistant corals that survived the temperature-driven bleaching event. Over time, this could lead to heat-tolerant species increasing their distribution range into habitats previously dominated by other species.
- Synergistic effects: Factors not previously recognized as important to resilience, such as robust tissue regeneration, high competitive ability of the corals, seasonal dieback in a seaweed bloom, protection afforded by an effective marine protected area system, and

moderate-to-good water quality, can result in rapid coral recovery (Diaz-Pulido et al. 2009).

4. Management Interventions

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 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 tab 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.

Social Resilience

This tab focuses on the impacts of climate change on social resilience. Social Resilience is defined as the ability of a community to cope with and adapt to stresses such as social, political, environmental or economic change. The manager's role in supporting the adaptive capacity of a community is discussed.

Table of Contents

Social Resilience: Training Guidance

Estimated Time
45-60 minutes – Powerpoint Presentation
30 minutes – Activity: Group discussion

Seating Arrangement/Group Size
Full Session – Up to 25 students (absolute max is 30)

Learning Objectives
By the end of this training students will:
- ✓ Understand the basic concepts of social resilience
- ✓ Understand why social resilience is important for a community to withstand the impacts of climate change
- ✓ Understand adaptive measures to help overcome threats to social resilience
- ✓ Know where to look for more resources on social resilience

Activity Description
1. Give Powerpoint Presentation: Social Resilience (45-60 minutes)

2. Conduct group activity: Discussion about Social Resilience (30 minutes) (Note: This activity can be done as a large group or you may divide into small groups, smaller groups will usually result in participation from more students so if possible it is recommended to split into smaller groups)

   Discussion Questions:
   - How would you define social resilience in the context of your community or site?
   - What challenges does your community face when it comes to social resilience?
   - What potential impacts of climate change do you think will impact your community/site the most, and how might you support adaptation measures that will reduce social vulnerability?
   - What strengths does your community/site have in terms of social resilience?
   - What lessons can be learned from past threats to your community/site's social resilience? Which management actions have supported the community in the past and helped overcome threats?

Materials Needed
- Powerpoint Presentation: Social Resilience (Flash drive)

Social Resilience: Background Information

1. What is Social Resilience?

The fates of coral reefs and millions of humans are entwined through intricate webs of inter-dependence. Building resilience of these complex social-ecological systems requires that coral reef managers consider the dynamics of both the ecosystem and linked social systems. Understanding social resilience, and its implications for ecosystem management can increase the ability of managers to achieve conservation goals while maximizing long-term benefits for coastal communities and reef-based industries.

Social resilience is defined as the ability of a community to cope with adapt to stresses such as social, political, environmental or economic change. It shares much with the concept of ecological resilience, but with an important difference: humans have the ability to anticipate and prepare for future conditions. For managers, this means that there is scope to work with reef-dependent communities to understand their vulnerability to changes in reef condition and support adaptation efforts. Healthy and prosperous people have more options available to them and thus are more capably of ensuring their activities are supporting, rather than eroding, ecosystem resilience. Management programs that value sustainability of coastal communities are also more likely to benefit from stronger community support, reduced transaction costs and increased compliance. In short, coral reef managers that invest also in supporting ecosystem-based adaptation in coastal communities are more likely to achieve their long-term conservation goals.

Social vulnerability and resilience

Social vulnerability can be generally defined as a measure of the presence or lack of ability to withstand shocks and stresses to livelihood or wellbeing. Vulnerability is usually considered to comprise three components - exposure, sensitivity and adaptive capacity. Exposure and sensitivity determine the potential impact that a system could experience, while adaptive capacity moderates potential impact to determine total vulnerability. Resilience can be considered the aspects of vulnerability that determine how a system copes with exposure to change. In other words, resilience is a combination of sensitivity and adaptive capacity. Often resilience and vulnerability are viewed as opposites of each other, and this holds true for any particular exposure scenario. However, resilience is best seen as the properties of the system that determine its ability to cope with exposure, and vulnerability is the outcome of a system of particular resilience subject to a specific exposure. The concepts of exposure, sensitivity, potential impact and adaptive capacity are explored briefly below.

Exposure

Reef-dependent communities and industries are affected by changes in coral reef ecosystems. The type and amount of change is variable in space and time, meaning that different communities and sectors will vary in their exposure to ecosystem change. The amount of exposure determines the amount of resilience required to achieve a particular reduction in vulnerability. Coral reef managers and researchers are important sources of information on predicted changes to reef ecosystems, and can be key contributors to efforts to assess vulnerability. For fishers, exposure may take the form of reduced stock of targeted species, while for a tourism business it may be decreased aesthetics of coral reefs at key tourism sites.

Sensitivity to change
Communities and individuals that are more dependent on the goods and services provided by reefs are more sensitive to change in ecosystem condition. An understanding of dependency provides an indication of the sensitivity of the social system, which when combined with knowledge of exposure (predicted changes in resource condition/availability) can help managers assess potential impacts. People can be dependent on coral reef because of social (e.g. place attachment, occupational identity, family circumstances, employability and extent and quality of networks), economic (e.g. income, size of business and business approach) and environmental (resource use, specialization, values, attitudes, perceptions and understanding of threats) attributes.

Potential impact
Potential impacts describe the vulnerability of a system in the absence of adaptation. For example, the potential impact on a fishery of predicted declines in stocks of targeted species might be complete economic collapse if businesses do not adapt.

Adaptive Capacity
Adaptive capacity relates to the ability of people to convert resources (including financial, natural, human, social or physical) to adapt to a particular exposure scenario given their sensitivity to change (i.e. their resource dependency). This might translate, for fishers for example, into their ability to invest in alternative fishing gear, acquire new skills through learning and form a cooperative to diversify catch composition and increase profit yields to compensate for reduced stocks of target species. Key attributes associated with adaptive capacity are:

- Ability to manage risk and uncertainty
- Possession of skills for strategy, planning, experimenting, learning and reorganizing
- Buffers for absorbing change
- Interest in change

2. Management Strategies: Assessing Social Resilience
Management strategies to build resilience in human communities that are highly dependent on coral reef resources can take many forms. There is no single approach that will guarantee the robustness of social systems associated with the marine environment. Sometimes the social system is already in a desirable state, and the challenge is to ensure that the state is not degraded. Other times, a social system may be in an undesirable state and the challenge is to move towards a more desirable state. Knowledge of the resilience of resource users to changes in resource-use policies can assist in the design and implementation of policies that minimize the impacts on people while maximizing the sustainability of ecosystem goods and services. A driving factor in the response of resource users is their resilience to policy change. The ability of

resource users to cope with and adapt to changes in the rules that govern their access to natural resources will determine their willingness and capacity to comply and will determine, as well, the social and economic impacts of their response.
Managers who wish to work with communities and industries to build social resilience may find the following steps useful in guiding their engagement strategy:

- Identify communities and sectors that depend on goods and services from coral reef ecosystem
- Characterize the nature and strength of dependencies on the coral reef system
- Assess the implications of predicted ecosystem changes (including policy changes) for dependent communities and sectors
- Explore adaptation options
- Identify strategies that can simultaneously build social and ecological resilience
- Support efforts to build adaptive capacity

Coral reef managers will benefit from partnerships with social scientists in designing and implementing social resilience programs, but a familiarity with relevant concepts and tools can help managers integrate social considerations into management programs.

Vulnerability assessments are a critical first step for reef managers to support efforts to reduce vulnerability and build resilience in human communities. The results of social vulnerability assessments can provide a better understanding of the conditions and characteristics of resource-dependent communities at their site, and highlight opportunities for climate adaptation. Before managers begin collecting social data, it is important to have clear objectives that guide the data collection. There are many resources available to reef managers to collect social information. In addition to these, there are protocols that specifically aim to collect social information for climate adaptation. The resources are complementary and managers should use a combination of strategies and methods, depending on needs and circumstances.

A range of resources are available to guide efforts to build social resilience. These include tools for assessing and monitoring social conditions and resources for understanding social resilience, assessing vulnerability and guides for exploring adaptation options including:

- SocMon (www.socmon.org)
- The Local Early Action Plan (http://pimpac.org/images/file/VA_LEAP_FINAL.pdf) for climate change adaptation is a step-by-step guide which helps managers and communities develop a vulnerability assessment to support climate change adaptation. Developing a LEAP includes identification of priority social and natural resources, identification of threats, characterization of the vulnerability of priority resources to climate change impacts, identification of potential solutions to address threats and to reduce vulnerability to climate change impacts, identification of desired results and measurable objectives, and development of an action plan to achieve those results.
- The Sustainable Livelihoods Enhancement and Diversification (https://cmsdata.iucn.org/downloads/sled_final_1.pdf). The SLED approach focuses on

livelihood assets and is a participatory process of discovery, direction-finding and implementing. SLED helps community members identify under-utilized assets and livelihood options and develop sustainable, locally appropriate income-generating activities based on them.

- Community-based Risk Screening Tool – Adaptation and Livelihoods (http://www.iisd.org/cristaltool/). CRiSTAL is a planning and management tool designed to help project designers and managers assess the impacts of a project on the climate vulnerability of project beneficiaries, and adjust project activities to improve their impacts on climate change resilience. It uses a holistic view of the local climate and livelihood context to generate information that supports an assessment of the impacts of particular interventions.

Communicating Resilience

This tab focuses on how to communicate complex problems such as climate change and coral bleaching to a variety of audiences. It highlights some communication challenges and some rules of thumb that will improve your communication approach. The Training Guidance includes instructions for leading an audience through writing a draft of a Communication Strategy.

Table of Contents

Communicating Resilience: Training Guidance

Estimated Time
30-50 minutes – Powerpoint Presentation
20 minutes – Discussion
Possible Group Activities:
60 minutes - Activity: Drafting a Communication Strategy
30 minutes - (Optional: Presenting your Communication Strategy)

Seating Arrangement/Group Size
Group Activity – 4-5 students per group max with facilitator – can group students by geography or mix – either way works well
Full Session – Up to 25 students (absolute max is 30)

Learning Objectives
By the end of this training students will be able to:
- ✓ Identify different audiences and think about how to tailor communication strategies to target each audience
- ✓ Learn how to communicate Climate Change, Coral Bleaching, and Resilience to their target audience
- ✓ Identify innovative ways others are communicating to the public and stakeholders
- ✓ Draft a tentative Communication Plan for use at their site

Activity Description
1. Give Powerpoint Presentation: Communicating Resilience (30-50 minutes)

2. Facilitate a discussion about communication challenges and examples (20 minutes)

3. Conduct Group Activity: Drafting a Communication Strategy (60 minutes)

   Purpose: To develop a communication strategy that is appropriate for your problem and place.

   Instructions:
   - Divide group into smaller groups. Depending on the make up of the training participants they can work with partners or small groups of 4-5. It is important to divide them in groups that make sense for a realistic outcome so pair up partners who will work together after the workshop is over if possible.
   - Distribute the handout to each person. Give participants the following information and instructions: In this exercise, you are going to begin to develop a communication strategy that is specific to 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, community meetings,

presentations to stakeholders, 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.
- Fill out the Communication Strategy Handout, working with your small group for feedback as needed. You may work with a partner from your site.

  Output: Communication strategy draft developed

4. OPTION: You can choose to focus on a few sections of the Communication Strategy (Target Audience and Methods of Communication, for example), depending on needs and time available, or work through the entire plan.
5. OPTION: Group presentations of communication plans: at the end of the session, each person has 5 minutes to present specified highlights of their communication plan (Example: target audience, methods and messages). Re-divide the larger group into smaller groups so that each person presents to a different small group.

Notes to the Instructor/Additional Resources

- 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.
- The Big Mamma Song and campaign materials can be downloaded on the website for anyone interested (also available on the flash drive).
- Rare Conservation Communication Campaigns: http://www.rareconservation.org/success-stories

Materials Needed

- One Communication Strategy Handout per person (on flash drive)

Communication Strategy Handout

Instructions: In this exercise, you are going to begin to develop a communication strategy that is specific to Reef Resilience that will assist you in successful implementation of your management strategies. This strategy may be hypothetical, or may be a plan that you intend to put into place. Your main message or theme may be delivered in a variety of ways (for example: advertising campaigns, school programs, radio show, a video, a presentation, brochures and/or a workshop). The most important thing is to make sure it is focused and outcome-oriented. Follow the steps in the Communication Worksheet to complete this exercise.

Output: Components of a communication strategy

Step 1: Identify Resilience issue of concern (see helpful questions below)

Helpful Questions

1. What is the problem your project is planning to address?
2. What are the most common or serious consequences of the problem?
3. Who are the people most affected by the problem?
4. Are there specific groups or individuals that are causing the problem?
5. What are the possible ways to address the problem?
6. Who are potential experts you should interview to get more information on the problem?
7. Does it have an emotional element that people would respond to?

<u>Examples of Issues of concern</u>:

- A local community has limited knowledge about the impacts of climate change
- Overfishing is causing reef degradation
- Coral bleaching is threatening the local coral reef
- The local community is not involved in developing a management plan for the protected area

What is your resilience issue of concern:

Step 2: What is the goal for your communication strategy?

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

List your goal(s):

Step 3: Identify your target audience and secondary audiences for your communication strategy* (See helpful questions below)
**Note that the target audience refers to the group you are trying to influence* (for example, this might include policy makers, community members, fisher folk, a stakeholder group, or colleagues). *You will be able to identify groups that can HELP you with implementation later in the exercise.*

It is helpful to start by targeting those audiences that are 1) causing the problem we want to address, or 2) will be affected the most by management actions of the strategy. In order to make the most effective use of limited communications resources, it is important to develop a clear understanding of exactly why they think or act in the ways that they do:

Helpful Questions

1. Who has the potential to be negatively affected by any management actions?
2. Exactly who is causing the problem?
3. How are they causing it?
4. What do they currently think about the issue or problem?
5. What costs and benefits do they perceive in engaging in their current practice?
6. What would you ask them to do instead?
7. What would best motivate them to change? What help will they need?
8. What other audiences might be interested or relate to this message?
9. Who will be most positively affected by any management actions?
10. Who will be involved in the implementation of management actions?

Please fill out this table:

Target Audience	Description	Rationale

Identify Secondary Audiences
A successful communication strategy is usually involves gaining support from key decision-makers responsible for allocating resources and developing policies necessary to achieve project goals. Identifying and developing strategic alliances with, and communication activities for, community leaders, government and non-government organizations, politicians, and other groups and individuals may be necessary.

Helpful Questions

1. What groups or individuals are most likely to influence the perceptions and actions of your target audience? (This may also include mass media.)
2. Who usually causes confusion or trouble when information is distributed to the public or your key audience?
3. Who does your target audience trust to provide them with accurate information?
4. Who do they usually ask questions about the topic?
5. Which audiences have the most political influence?
6. Which audiences have the most social influence?
7. Will the target audience respond better to a peer, an authority figure, or a celebrity associated with your issue?

Please fill out this table:

Secondary Audience	Description	Rationale

Step 4. What are the key messages that you want your communication strategy to convey to your target audience?

These key messages will be a call to <u>action or change</u> that will inspire your target audience.

Examples:
Key Message: Dynamite fishing is bad for the coral reef. Help stop dynamite fishing.
This is not a good message: It is not clear how the target audience benefits from stopping dynamite fishing.

Better Key Message: Dynamite fishing results in fewer fish to catch in the future. By helping to stop dynamite fishing, you protect your future income and continue to provide food for your families.

Fill in your key messages:

Step 5: 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?

Consider all aspects below to determine ranking:

1. What is the least expensive method of communication?
2. Do you have existing resources or education programs that you could build on?
3. Are there specific education or outreach campaigns/programs that you can expand?
4. Are there resources in your community to help you implement your strategy?

Please fill out this table:

List the chosen method(s) of Communication:

Method of Communication	Feasibility Ranking (1-5) 1 = least feasible 5 = most feasible		Notes
	Based on cost of message	Based on effectiveness of message	

Step 6: Identify individuals, organized groups, resources or institutions that can help or support implementation

Helpful Questions

1. Does your area or for your site have existing outreach or communication programs?
2. Are any school programs in place that have environment or ocean classroom programs?
3. Are there particular teachers in your community with an interest in developing such programs?
4. Is there a strong community organization, NGO, or group in your region that works with your target and/or secondary audience?
5. Do you have TV or radio shows that highlight or discuss local issues?
6. Are there annual events that most of the community participates in? (e.g., agriculture exhibits, weekly markets, social events, religious events)

Resource	Description of Potential Contribution

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

Potential Needs	Yes/No	Notes
Funding		*What will funding be used for? (transportation? materials? venue rental?)* *Approximate amount of funding needed:*
Expertise		
Materials		*What types of materials (paper? posters? equipment?)* *Where will materials be obtained?* *What quantity will be needed?*
Other		

Step 8: Layout a preliminary timeline for the next six months for activity or program implementation

EXAMPLE:

Timeline (fill in your activity here) Ex. Resilience Workshop			
Timeframe (by month)	Activity Description	Milestones	Outcomes
August 2013	Assess community interest in participating in a Resilience workshop	1. Approach village leaders about workshop 2. Develop workshop agenda 3. Decide on dates for workshop	Tentative date scheduled for workshop
September 2013	Decide on presenters for workshop	1. Ask colleagues on reefresilience.ning.com for suggestions for presenters for workshop 2. Contact presenters 3. Confirm their participation	Presenters confirmed for workshop
October 2013	Logistics for Workshop	1. Book flights 2. Book hotel rooms 3. Confirm projector and screen 4. Order presentation materials	Logistics arranged
October 2013	Presentation draft	1. Draft powerpoint presentation 2. Use reefresilience network.ning.com to find colleagues with posters to use	Draft of presentation ready to present to office co-workers; informational posters found from colleagues on reefresilience.ning.com
November 2013	Presentation finalized	1. Print posters 2. Practice presentation with co-workers and make final changes 3. Confirm other presenters 4. Confirm dates with village	Final presentation ready, other presenters confirmed, posters printed
December 2013	Village Workshop	Have a successful Resilience Workshop!	Villagers aware of the importance of Reef Resilience

Timeline (fill in your activity here)			
Timeframe (by month)	Activity Description	Milestones	Outcomes

Communicating Resilience: Background Information

1. Importance of Coral Reef Ecosystems

Communicating the general importance of coral reefs and the value of reef services is a fundamental part of any management strategy. Without a compelling reason to invest and take action in coral reef management, communities and stakeholders can fail to take action and implement even the most basic management measures. A series of coral reef facts is shown below and may be useful when speaking with different key audiences and stakeholder groups. These facts can be useful in promoting awareness of the importance of coral reefs and in motivating others to take action to protect these ecosystems.

Coral Reef Facts:

- Coral reefs are among the oldest ecosystems on Earth.
- Coral reefs support a phenomenal diversity of species and provide irreplaceable sources of food and shelter to many fish species, including juvenile fish. Tropical rainforests play a similar role on land.
- Coral reefs exceed rainforests in their diversity.
- Although coral reefs cover less than 1% of the Earth's surface, they are home to 25% of all marine fish species.
- Coral reefs support approximately 4000 species of fish and 800 types of corals.
- Corals are an integral part of the reef; they are the foundational species that provide reef structure. Corals are especially vulnerable to human activities and to climate-related threats.
- Corals have shown remarkable resilience through major climate events and sea level changes, giving hope for their continued survival.
- Most coral reef dependent countries and territories are small island states, located mainly in the Pacific and the Caribbean.

Ecosystem Services: People Need Reefs

Natural ecosystems provide a number of services that benefit people directly. For coral reefs, these ecosystem services include fish production, shoreline protection, and opportunities for tourism and recreation. The Millennium Ecosystem Assessment analyzed the consequences of ecosystem change for human wellbeing, and identified four categories of ecosystem services:

1. 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)

Below are some key facts on many of the critical values and ecosystem services provided by coral reefs that can help to communicate the value of coral reefs to stakeholders.

Critical Values and Services of Coral Reefs

- Coral reef ecosystems support a variety of human needs. They are important for subsistence, fisheries, tourism, shoreline protection, and yield compounds that are important in the development of new medicines.
- At least 500 million people rely on coral reefs for food, coastal protection, and livelihoods.
- Over 275 million people worldwide live in direct vicinity of coral reefs (within 30 km of reefs and less than 10 km from the coast), and approximately 850 million people live within 100 km of coral reefs.
- In developing countries, coral reefs contribute about one-quarter of the total fish catch, providing food to an estimated one billion people in Asia alone.
- Coral reefs form natural barriers that protect nearby shorelines from the eroding forces of the sea, thereby protecting coastal dwellings, agricultural land and beaches. More than 150,000 km of shoreline in 100 countries and territories receive some protection from reefs.
- Coral reefs are the medicine chests of the 21st century, with more than half of all new cancer drug research focusing on marine organisms. Coral reefs have been used in the treatment of cancer, HIV, cardiovascular diseases, ulcers, and other ailments.

Economic Value of Coral Reefs

The economic value associated with ecosystem services can be derived in a number of ways, including estimated costs of replacing particular service~~s~~ with alternatives, such as installing a breakwater to replace coastal ecosystems that shoreline protection in the past. The on-going efforts to assign economic value to nature are revealing new opportunities to manage our environment for more sustainable use and longer-term prosperity. Below are a few key points about the economic value of coral reefs:

- It is estimated that coral reefs provide $375 billion per year around the world in goods and services
- At least 94 countries and territories benefit from reef tourism. In 23 of these, reef tourism accounts for more than 15 percent of gross domestic product (GDP)
- People the world over visit coral reefs to enjoy the recreational activities provided by coral reefs, including SCUBA diving, snorkeling, and glass-bottom-boat viewing
- In one estimate, the total net benefit per year of the world's coral reefs is $29.8 billion. Tourism and recreation account for $9.6 billion of this amount, coastal protection for $9.0 billion, fisheries for $5.7 billion, and biodiversity for $5.5 billion
- The global costs of coral bleaching are calculated to range from $20.0 billion (a moderate bleaching scenario) to over $84.0 billion (a severe bleaching scenario).
- The contribution to employment of a healthy Great Barrier Reef to Australia's economy is estimated at 53,800 full time jobs

1.1. Reefs are at Risk

In addition to understanding and communicating the importance of coral reefs, it is also critically important for a coral reef manager to understand and communicate the extent to which reefs are at risk. Below are key findings from the 2011 report Reefs at Risk Revisited report that quantified the current threats to coral reefs worldwide and projected the risk of future degradation.

Status of coral reefs worldwide:

- Approximately 75% of coral reefs worldwide are currently threatened by a combination of local and global stressors.
- Coral reefs are experiencing higher ocean temperatures and acidity than ever before in the last 400,000 years.
- Over 60% of coral reefs worldwide are directly experiencing one or more local stresses.
- Fishing threats (including overfishing and destructive fishing) affect the most coral reefs worldwide—more than 55% of reefs.
- By 2050, almost all reefs will be classified as threatened by the combination of global impacts.
- Without actions taken to minimize local stressors, the percent of threatened coral reefs worldwide will rise to 90% by 2030 and close to 100% by 2050.

Threats in different coral reef regions:

- Almost 95% of coral reefs in the Southeast Asia region are threatened.
- Indonesia has the largest area of threatened coral reefs, with fishing threats being the main stressor on coral reefs.
- More than 75% of the coral reefs in the Atlantic are threatened. In over 20 countries and territories in this region, all coral reefs are rated as threatened.
- Over 65% of the coral reefs in the Indian Ocean and the Middle East are under stress by local threats.
- Nearly 50% of coral reefs in the Pacific are threatened.
- Approximately 14% of Australia’s coral reefs are threatened, though it is ranked as the least threatened coral reef region.

Increases in threats to coral reefs over the last decade:

- The percentage of threatened coral reefs has increased by 30% in the 10 years.
- Increases have occurred across all local threats and all regions of the world.
- Fishing threats (overfishing and destructive fishing) has increased by 80% in the last 10 years, making it the greatest stressor to coral reefs worldwide.
- Mass coral bleaching has now occurred in every region of the world.
- It is projected that during most years the 2050s, 95% of coral reefs will experience high thermal stress potential bleaching.
- Due to ocean acidification, it’s projected that by 2050 only about 15% of coral reefs will be in areas where aragonite levels are adequate for coral growth.
- 27 countries and territories are identified as highly vulnerable to reef loss across the world’s reef regions; 19 of these are small island states.

It is important to communicate the status of coral reefs on the local level. This information can often be difficult to find or access. For country level information on the threats to reefs you can contact the World Resources Institute.

2. Effective Communication: Writing a Communication Strategy

Effective communication is an essential component of any successful coral reef management strategy. When outreach and communication are not incorporated into reef management strategies, key resource users may not be informed of the purpose behind actions or changes in regulations. This can lead to misinformation, anger, or dissent, and can ultimately result in harmful effects to reefs. It is important to communicate with stakeholders, partners and colleagues throughout the development and implementation of any project or strategy. The investment put into communication planning at the start of a project will lead to better results. Strategic communication is a valuable tool to help achieve the following goals:

- Changing certain behaviors among certain people
- Encouraging people to participate in certain activities
- Gathering stakeholder perspectives and additional information that can strengthen or improve a project or management plan
- Persuading or convincing people to believe or accept new ideas or solutions
- Informing others about what your project is and does
- Increasing political and community support
- Raising awareness of issues and solutions

A communication strategy is an important tool when a project team identifies a lack of knowledge, lack of awareness, or unfavorable attitudes that are affecting conservation goals. A communication strategy is designed to influence people's knowledge, attitudes, and actions. Developing a communication strategy involves specifying clearly defined communication objectives and developing a set of coordinated messages, activities, and products to achieve them.

In order to determine the need for a communication strategy, it is important to consider the extent the lack of knowledge or unfavorable attitudes are contributing to the overall problem. If their contribution is minor, it may not make sense to use a communication strategy. Although large scale communication campaigns can be expensive, communication planning does not necessarily require thousands of dollars, or take months to complete. The investment put into communication planning at the start of a project will lead to better results. A completed communication strategy includes the following components:

1. The main issue of concern and the **goals and objectives** of the strategy: The priority issues, which might include coral bleaching, management effectiveness, general reef health, or coral reef resilience. One goal might be to increase knowledge of the concept of resilience. An objective could be to change the behavior of a specific resource user group so that the threats to reefs are reduced.
2. A plan for **pre-testing** and audience research messages and products with a segment of the target audience to assess effectiveness

3. Target **audience(s)**: The main group of people a manager is trying to reach
4. **Key messages** and a call to action to engage your target audience and get them to act.
5. The best **methods of communication**: Exactly what methods, products, activities or materials will be used for communicating with the target audience
6. **Resources and needs**- These include funding, access to experts, presenters, venues or presentation materials that can be used to accomplish a communication strategy.
7. A **timeline-** The specific steps and timing for completion of each step to accomplish the communication strategy.
8. **Evaluation** to examine if the message and strategy has had the intended impact on the target audience

A simple communication strategy will not take a long time to develop and will help a manager think through various facets of a communication that they may not have otherwise considered. Use the **Communication Strategy handout** developed to help guide managers through the process of creating a communication strategy specific to coral reef resilience.

For a communication strategy to be most effective, it is important to have someone with communication experience as a member of the project team or assigned to support the team. If this is not available, it may be necessary to seek external support.

2.1. Setting Communication Goals and Objectives

The first step in writing a communication strategy is to determine the goals and objectives. The strategy goals should define a vision for what is to be reached in the future. The objectives should be specific and short-term outcomes, related to the main issue of concern, and be achievable by communication efforts. A strategy goal of "more awareness" is not an effective goal. It is important to understand the underlying reason why more awareness is needed. Is the need for more awareness it to attract more funding for a program, encourage more visitors to a MPA or to reduce conflict within a community? Goals and objectives that clearly specify the desired outcomes will result in a more effective communication strategy.

Goals and objectives depend on the assessment of the main issue of concern. If the problem is that a community doesn't understand the benefits of the management systems, then it might be determined that an education effort is needed. If the problem is that businesses are not complying with fishing regulations and are buying undersized fish, then it might be appropriate to implement a targeted project that identifies champions who can advocate in that industry for behavior change.

What is the difference between goals and objectives?

- A **goal** is broad statement of the ultimate aims of a program/project or strategy.
- An **objective** is formal statement detailing a desired outcome of a project, such as reducing a critical threat. A good objective meets the criteria of being results-oriented, measurable, time limited, specific, and practical. If objectives are clearly measurable it will be easier to identify and communicate successes with the target audiences and partners.

Tip: Goals and objectives should be explained in three bullet points or less.

The following questions can help determine the main issue of concern and strategy goals:

- What is the problem that the communication strategy is trying to solve?
- What are the most common or serious consequences of the problem? Why is there a need for solutions to this problem?
- Is it getting worse?
- Who are the people most affected by the problem? Describe them (young, old, from a certain area)?
- Are there specific groups or individuals that are causing the problem?

The following questions can help determine strategy objectives:

- How can the problem be measured?
- What are all the possible ways to address the problem?
- What are the most cost-effective ways to prevent the problem?

Once the main issue of concern, goals, and objectives are determined it is important to find out as much as possible about the specific problem the communication strategy will address. This should include the situation or context in which the problem occurs and the audiences you are targeting. Some good questions to help begin assessing the context of the problem include:

- Who are potential experts that should be contacted to get more information on the problem?
- What trends or other factors might affect the situation or circumstances in which the communications will take place?
- Which groups, community leaders, or other individuals might support or oppose the project or campaign?
- Are there any policies or laws that might affect the communication strategy?
- Are there any other projects or communication efforts addressing the same issue?
- What external opportunities could the communication efforts take advantage of?

2.2. Pretesting and Audience Research

After the goals of a communication strategy have been determined it is important to understand how researching the audience, and pretesting both messages and methods contribute to successful communication efforts.

Depending on the project scope and budget, there are a variety of approaches to research and testing that can be done including:

- Audience research: By gaining a better understanding of WHO is doing WHAT, audience research is helpful when selecting a target audience. It can also provide information on the awareness and attitudes of people towards a specific issue as well as the media usage of different audiences. Audience research can serve as a baseline for post communication efforts evaluations.

- Pretesting key messages and methods helps determine if a message will be understood or effective for achieving the desired objectives. It is also used to understand the target audience's trust in various communication methods and their response to proposed behavior change. Pre-testing can be done on a representative sample of the target audience through telephone or mail surveys. It can also be done more simply by assembling a small group from the target audience and showing and discussing the communication tools with them. For example a manager could gather a small group of fishers, show them a presentation or brochure, then take notes on the feedback from the group. By pretesting, the project can adapt messages and methods if needed, and avoid mistakes and unexpected effects from communication.

Research Methods

Methods can be either qualitative (e.g. asking people questions), quantitative (e.g. counting how many people think or do something), or a combination of the two. Examples include focus groups, interviews, surveys, or observation of sample target audiences. The size of the target audience may influence the methods. With large audiences, quantitative tools may be easier. With smaller audiences, qualitative tools such as focus groups and interviews are more effective.

By segmenting audiences into groups with similar needs, and tailoring messages and products to each group, the communication strategy can be more effective. It also helps to identify groups of people who are like each other (e.g. have the same views or habits) and more likely to respond to particular messages in similar ways. Possible groups could be based on age, location, income, occupation, lifestyle or ethnicity.

When determining what types of pretesting and audience research will be conducted, it is important to also consider any evaluations that will be done at the end of the communication effort. By thinking ahead about evaluation it is possible to include questions in pretesting that will establish a baseline for evaluation.

2.3. Identifying the Target Audience

Managers responsible for communicating about coral reef health and resilience often need to be creative and innovative to gain support from different audiences. Whether dealing with school children, community members, government officials, fishers, the media, industry, or academics, a well-planned communication strategy or campaign tailored to the target audience is needed.

When developing a communication strategy, one of the most critical steps after determining the goals and objectives is the identification of the target audience for the project. The key thing to remember is that, for the purposes of communication, there is no such thing as the "general public." That is, outreach materials aimed at the "general public" are too general to be effective in their messaging. "Target audience" refers to the group a manager is trying to influence. Some key audiences that reef managers commonly target for communication efforts include policy/decision makers, community groups or resource users. The following questions can help determine possible the target audiences:

1. Who is causing the problem?
2. How are they causing it?
3. What other audiences might be interested or relate to the project message or goal?
4. Which audiences have the most political influence?
5. Which audiences have the most social influence?
6. Who shares information in this particular location? Who has the most influence on this particular audience?
7. Who will be most positively affected by the project/management actions?
8. Who has the potential to be negatively affected by the project/management actions?
9. Who will be involved in the implementation of the project?
10. Who usually causes confusion or trouble when information is distributed to the public or the key audience?
11. Who is directly involved in using and/or taking resources from the reef?

After determining possible target audiences it is necessary to identify the primary and secondary audiences of the communication strategy or campaign.

Primary Target Audience: The key persons or groups that should be communicated with directly. There may be more than one primary target audience for the communication strategy.

Secondary Target Audience: People or groups who are less relevant to the communication efforts but who need to receive the communication or messaging. They will also benefit from hearing the messages, or they may be able to influence the target audience now or in the future.

Target audiences can be narrowed down by considering the following:

- What specific action or behavior needs to be changed to address the objectives or solve the issue at hand? In many cases, the majority of communication efforts should be targeted toward the audience most directly able to change the situation.
- Which audience best helps meet the specific strategy goals? Keep in mind whose behaviors need to be changed with the communication strategy. These are the people that should be the target audience.
- Is the audience persuadable? It may be more effective to focus on key influencers, such as community leaders, business leaders, or progressive clergy who can “bring others with them” if their support is gained through the communication strategy.
- Can the target audience realistically be reached with program resources?

Note that in some cases, it will not be effective to direct communication at certain audiences (e.g., if they cannot be reached effectively or if they are not likely to change their behavior). In those situations, it may be better to select other audiences that can function as intermediaries for reaching them.

Audience Research
When identifying the primary target audience, it is important to be specific and assess the current behavior of the audience, their level of knowledge and awareness of the issue, their preferred methods of receiving information and their motivations (or barriers) to receiving the information. If more information is needed on the knowledge, attitudes, and awareness of the target audience, a variety of research methods are available.

Once the audience for the project is determined, it is then essential to identify key messages and the most appropriate methods for successful communication.

To better understand strategies for communicating with different target audiences, the two case studies below highlight innovative communication campaigns that focus on coral reef health. These examples introduce different communication techniques and provide a detailed overview of the communication efforts and audiences.

2.4 Messages

After defining communication objectives and target audiences, the next step in development of a communication strategy is to determine key messages and calls to action to influence the attitudes, affect the behaviors or increase the knowledge of the target audience.

The key message should be a short memorable statement that should include a benefit for the target audience so they are willing to alter their behavior. An effective message needs to be compelling to the target audience, and does not simply restate the communication goals. A call to action describes in a few words exactly what action is desired from the target audience. It also gives the audience specific advice or alternative behaviors. The message might be for the audience to engage in new actions (use fishing nets with larger mesh), or alternatively, to refrain from some type of specific practice (stop dynamite fishing). Often, providing a specific action or alternative for what they <u>should</u> do may be better received and lead to more behavior change.

Research has shown that target audiences respond better to messages that are:

- **Consistent:** It is important that the message being presented is not contradicted by other sources. Furthermore, all communication from the strategy should have the same "look" and message.
- **Simple and clear:** Messages should present only one theme at a time. These types of messages are more effective at getting the message across and holding the attention of the target audience.
- **Personalized:** Messages that directly show how a certain activity can affect and benefit target audiences personally are more powerful than those that concentrate on the general effects of an activity.
- **Communicated through various sources**: People are exposed to different media and learn in different ways. There is a need to have different means of communicating the message (print, TV, radio, Internet, their peers, etc). The target audience is more likely

to absorb a message with increased exposure to the message. The target audience may also be more inclined to believe the message when it is repeated by different sources.

2.5 Methods of Communication

After identifying the goal of the communication strategy and the main issue of concern, the target audience and the key messages, the next step is to identify and rank the most effective methods of communication or message delivery. The choice of method will depend on what the communication strategy aims to achieve, the message to be communicated, and the profile of the target audience. When choosing the communication activities, it is key to remember that an audience's perspective may be very different from a coral reef manager's perspective.

Important considerations when deciding on communication methods:

- Overall cost-effectiveness of each potential method. For example, a TV advertisement may reach a large number of people, but could be very expensive (and time-consuming) to produce. In comparison, a radio ad might be less expensive.
- How most people in the target audience receive news and information. If members of the target audience don't receive a daily newspaper, holding a community meeting or a direct exchange with community leaders should be considered.
- The level of understanding that the audience has about coral reef ecosystems in general. It may be necessary to help the target audience connect the problems they perceive to the underlying drivers that are allowing these problems to persist or grow.

Consider the following criteria for each potential method of communication:

- How many people will it reach?
- What is the overall cost?
- How does the target audience prefer to receive their information?
- Who does the target audience listen to and trust?
- Does the audience consider the person or agency acting as the messenger a trustworthy source of information?
- Is this method culturally appropriate?
- How will this communication method be spread, and who will do the work?
- Is there a local "champion" or "ambassador" (people who are respected and connected to the target audience) who would be more effective at communicating this message?

Below is a chart that provides examples of effective methods of communication for specific key target audiences and tips for successful implementation. It is important to select a variety of methods that will connect with your target audience at multiple times and in multiple places, as change cannot be expected as a result of a one-time effort.

Target Audience	Communication Objective	Key Methods	Tips
Policy/Decision Maker (e.g., Governor, Director of Fisheries Agency)	Ensure that coral reefs are a management priority	Face-to-face meetings Briefings Media relations?	Provide info early Present actions and solutions Recruit community spokespeople
Community Members or Groups (e.g., Fisheries co-op, neighborhood board)	Increased understanding and/or involvement in behavior change	Meetings, TV/radio shows, Newsletters Skits or plays	Choose culturally-appropriate methods
Stakeholder Groups (e.g., dive shop operators, surfers or tourists)	Increased understanding or involvement in behavior change	Radio/TV/Newspaper Internet Social Media Posters Meetings	Decide on the most cost-effective way to reach a large number of people Use trade or affinity associations
Media	Increase knowledge of threats to reefs	Journalist workshop Press releases Conferences Trips/site visits	Use success stories to inspire positive change
Colleagues and Partner organizations	Share knowledge, identify information gaps, coordinate response and communication efforts	Telephone Email Websites Presentations	Mutual exchange of information Use the same overall messages – seek consistency

Other types of communication methods to consider include:

- Outdoor Advertising: sculptures/signs in public places, billboards (roadside, on buses, bus stops, at the airport)
- Point of purchase materials (at the shop counter, on shopping baskets)
- Posters, flyers, brochures or fact sheets
- Competitions and awards
- Creative products and events
- Presentations at a local school or church

- Grants
- Workshops and Trainings
- Educational materials (for teachers and students)
- Study packs, interactive games
- Media such as magazines, newspapers, flyers, radio advertising

2.6 Evaluation

The final step in implementing an effective communications strategy is the examination of what degree key messages and the methods of communication have had the intended impact. A typical communication evaluation looks at three different types of measures. What did the strategy achieve? How effective were the messages? Does the target audience remember the message? Do they understand the issues? And, most importantly, did it change their thinking or behavior)? The following measures can be a part of a successful evaluation:

- Measuring communications activities: This involves collecting data to count activities, materials, or other efforts related to the implementation of the strategy, such as how many leaflets were distributed, how many community meetings were held, etc.
- Measuring recall and recognition: This looks at the ability of the target audience to remember a message.
- Outcomes (behavior and attitude change): This involves determining the overall effectiveness by measuring shifts in target audience behavior or attitudes. One example of this method is conducting a poll immediately before the launch of a communication strategy and comparing it to the same poll after the conclusion.

Polling can tell you:

- If the audience heard the message
- If the message affected the audience's thinking about the issue
- If the message evoked a positive or negative response
- If the message changed people's behavior
- To what degree change occurred

It is important to be realistic about what communication efforts can achieve—and how quickly they can achieve it. Coral reef related communication strategies often aim for change at multiple levels of society (individual, community, state, or national) and address hard-to-achieve issues such as changing behaviors, beliefs, or public norms. While communication can help change the way people see an issue or persuade people to make a certain decision (about what to buy, what fishing method to use, or who to vote for), it's unlikely to see a significant attitude shift from a single effort at strategic communication. When looking to achieve long-term change in behavior, Social Marketing should be considered.

Definitions & References

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 λ = 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/

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