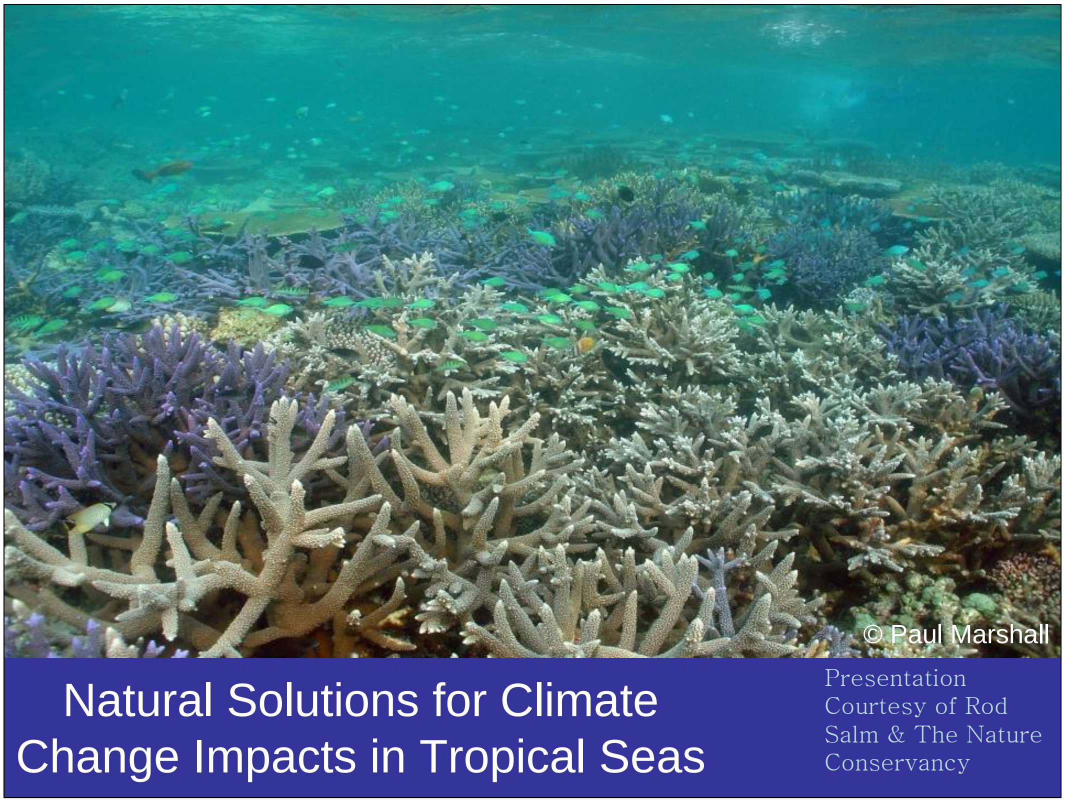


Good morning. It is my goal to leave you confident that places like this will always be there for all of us to enjoy despite the ravages of climate change; that investing in nature's infrastructure provides a viable alternative to construction in many cases to address climate change impacts on tropical shores; and that building resilience into ecosystems provides a strategy to cope with climate change impacts on both the environment and people.

One of the first and most dramatic responses in the seas to global warming is mass bleaching of corals. When corals are stressed by unusually high seawater temperatures, as we see happening now nearly every year over vast areas somewhere in the tropics, they respond by bleaching. Corals have tiny plant cells in their tissues that give them their color. When corals are stressed they respond by expelling these cells and they lose their color – or bleach. While bleached corals can recover, ones that are bleached too severely are unlikely to survive.

New challenges from climate change

Warmer Seas

Rising Seas

Disease

Altered Currents

Stronger Storms

Acidification

Rising seas linked to climate change probably do not pose a major threat to coral reefs as the projected rates of sea level rise are low enough for coral growth to keep pace. However, this is an issue for turtle beaches and mangroves. We should think about focusing on mangroves that are backed by low-lying salt flats so that the mangroves can advance inland as sea level rises. We should also focus on deltas and other areas of accretion so that the mangroves can colonize and expand there. We should also consider turtle beaches backed by coastal plains rather than narrow pocket beaches which are likely to erode or get covered by waves and high tides.

It is difficult to know how to respond to disease other than to manage reefs for maximum stress control and to promote health. Dust from sub-Saharan Africa carried by winds to the Caribbean brings aspergilis (a common airborne fungus) which causes disease of people and sea fans, killing sea fans. Also, the dust brings iron which enhances pathogen growth, partly explaining why there is so much disease in the W Atlantic reefs. Dust from the Gobi desert in China settles in Hawaii and may lead to similar problems there in the future.

It is expected that there will be an increase in frequency and severity of tropical storms. For changes in storm patterns we can monitor the impacts and identify areas that survive better than others because of their location in bays or the local bathymetry. These survival areas should get higher levels of protection and management.

There is little yet to say about changes in currents until we determine how they will change.

Increased CO2 and acidity will weaken corals and slow their growth. Areas of deep mixing may dilute these increases and help to protect corals from the effects of increased acidity while at the same time cooling heated surface water and protecting corals from bleaching.

What we are going to look at now is how global warming is causing corals to bleach and sometimes to die over huge geographic areas; and we will consider designing and managing MPAs for resilience as a strategy to address this phenomenon.

All these potential changes pose their own challenges for marine conservation; but we are going to focus on the threat of warming seas and how managing for resilience will help address this threat. This serves as a useful example of the approach managers can take where they are helpless to control the source of the threat. We will try to show that by managing for resilience, we can assist the way in which reefs can resist or recover from such large scale unmanageable threats, like climate change linked warming seas. Today, we will discuss some ways that you may be able to do this.

Invite questions: is everyone clear? We have control when managing for fishing impacts, etc. But we cannot control climate change or warming seas as coral reef managers – can only improve the way these reefs are managed so they can resist/recover from the threats these processes generate. This is what resilience is all about.

What is lost when corals die?

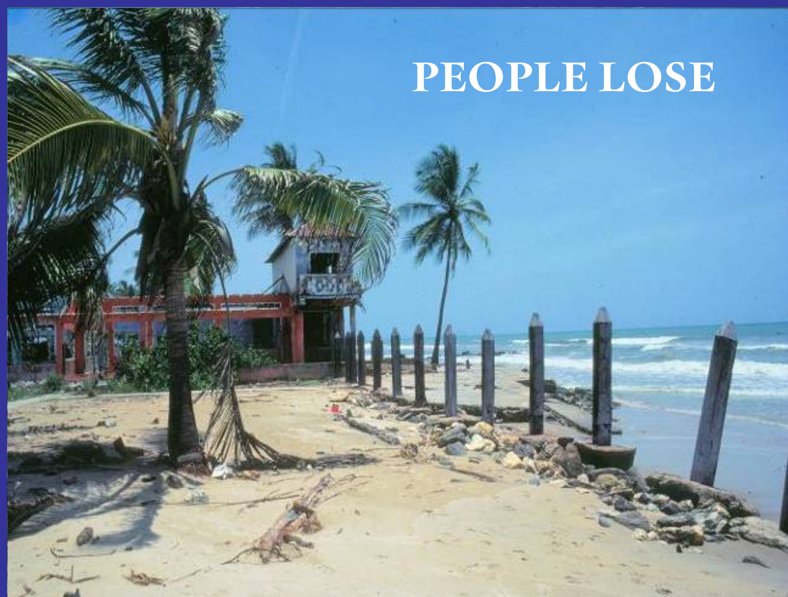
I would like to start by reminding ourselves what is lost when corals die. When this happens, the reef structure collapses, losing its value for biodiversity conservation, as a haven for fishes, as a food source, as a tourism destination, and as coastal protection. This compromises the livelihoods, food and income derived from the reef, and the security of coastal communities. When coastal protection is lost, beaches and whole islands disappear. For example, I saw an entire coral cay, the most important sea turtle nesting island off Tanzania, erode away and fall off the reef into deeper water after the fringing reef was destroyed. The turtles returned to haul out on the dead coral rubble that remained, but could not lay their eggs.

Replacing nature's infrastructure (mangroves and coral reefs) with built infrastructure (seawalls, groynes) to protect coastlines costs between $250K and $12M/km of coastline and we sacrifice the related ecosystem services valued at $31K-600K/sq km/yr, depending on the location..

What is lost when corals die?

Continuation of previous slides point

What is lost when corals die?



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Nature's Infrastructure provides …

Multiple direct benefits:

- Shoreline protection, food, jobs, carbon sequestration (mangroves)
- Sustainable development

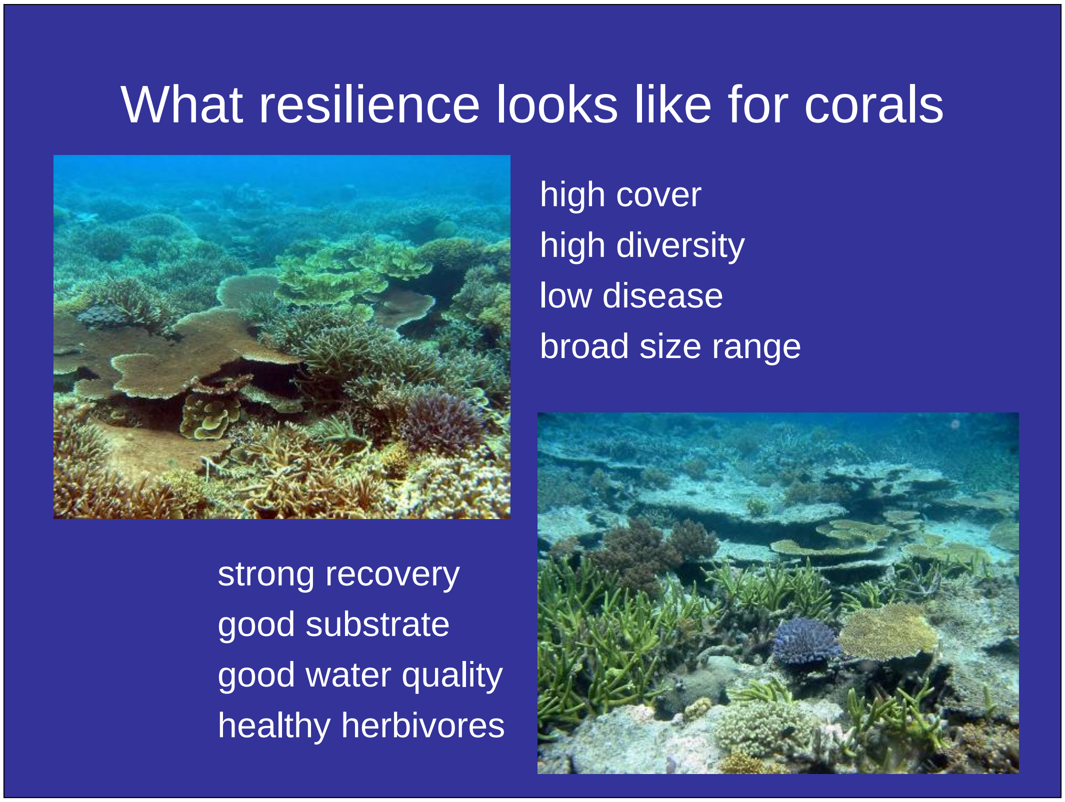
Cost effective, sustainable solution:

- Value of coral reefs: $31 – 600 thousand/sq. km
- Shoreline protection cost: $250,000 – $15 million/km

Strengthening the resilience of natural systems to threats – through conservation and sustainable resource management – is an important and cost-effective solution for protecting coral reefs and other ecosystems. Nature-based adaptation strategies not only strengthen the ability of people and communities to deal with climate change impacts, they contribute to the long-term viability of sustainable development efforts. For example, establishing networks of marine protected areas (MPA) to protect coral reefs that are most likely to survive in warmer seas can provide protection to coastal communities against storm and wave surges, while ensuring critical habitat for fish and other marine life.

Nature-based adaptation strategies can bring multiple benefits to people and nature, including protection from extreme events, reduced loss of life, decreased economic losses, and improved quality of life under climate change. Protecting and maintaining the health of the natural world will help reduce the negative impacts of climate change on human communities, and support sustainable development efforts. Nature-based adaptation strategies should be an integral part of climate change adaptation and development assistance, and a key component of a comprehensive international framework on climate change.

Note: reefs valued at up to $600,000/sq.km



What we look for when assessing the resilience of coral reefs includes indicators of the health of the reef like high coral cover, high biodiversity and disease-free corals, and a broad range in sizes. In the latter case the large old corals indicate a history of surviving or avoiding stress and the intermediate sizes and small young ones indicate regular strong settlement and good recovery potential – I was on an expedition to Indonesia where we found at least one venerable old coral that must have been in place during the time of Jesus. We also look for other indicators of recovery potential, like high recruitment of new corals in damaged areas. That itself tells us that the substrate is good, the water quality is good and there are good links with healthy reefs that provide the seed to repopulate damaged areas.

Scientists are finding that one of the key bottlenecks for resilience is lack of the right herbivores. Herbivores play an important role in making sure that algae/seaweed does not take over a coral reef. When herbivores are not present (either due to overfishing or some other cause), algae is able to take over and cause a phase shift from coral dominated to algal dominated. Scientists have found that specific herbivores play the maintenance role – ensuring the reefs are not overtaken and that other specific herbivores have been important in reversing phase shifts (able to remove large stands of macroalgae that have taken over). Knowing which herbivore species play these roles on your reef and noting their presence will tell you if you have healthy herbivore populations.

What resilience looks like for mangroves

high recruitment

high diversity

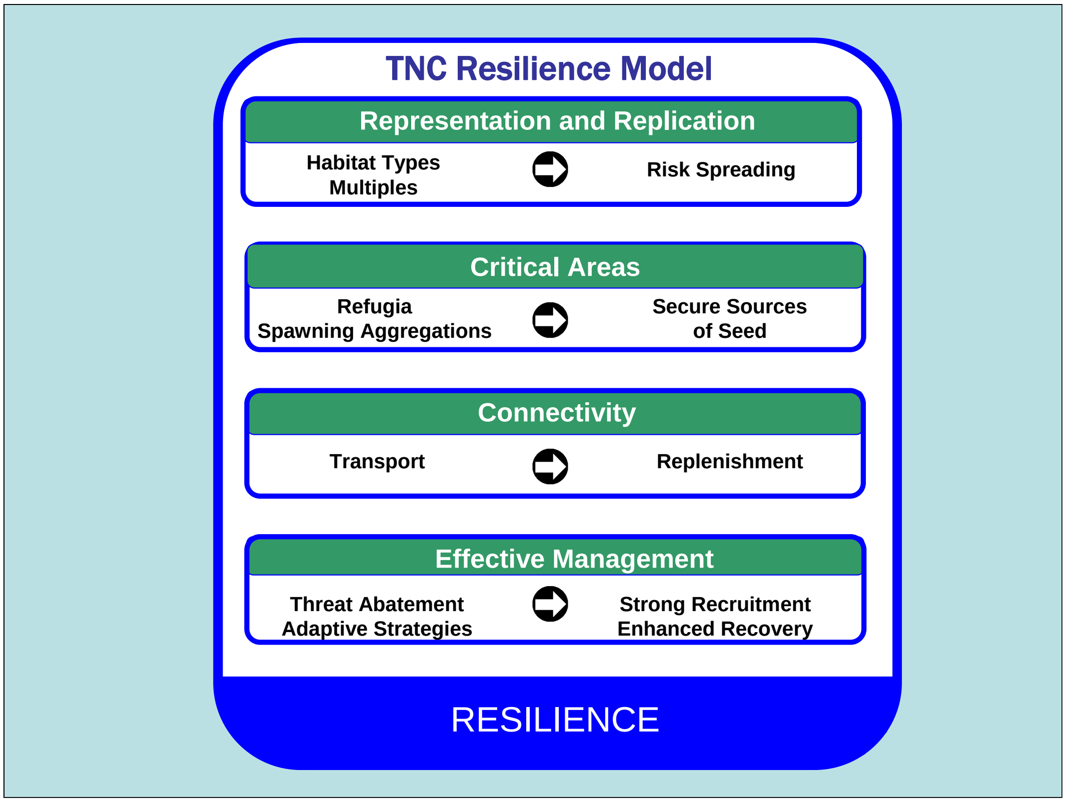
dense stands

established zones

room to expand

good hydrology

For mangroves we want to see good seedling production and settlement; that the mangrove stands are well developed and that there is a good variety of mangroves (or representation of existing mangrove diversity). We also want to see that there are well established zones in the mangroves which tells us that they have been around for some time without disturbance. And most important we need to determine whether they have flat land to expand onto as sea level rises and that the water supply is unimpeded so that the mangroves can grow and reproduce vigorously.



This is the simple four piece model that TNC uses to build resilience into the places we work. I will explain each of these pieces over the next several slides.

Introduction to Resilience Model

We are learning a great deal about the physiology of coral bleaching and how and why corals die, or don't, as a consequence. The story of bleaching resistance and resilience is complex. But, we are also learning that we cannot wait for perfect science; we need to arm ourselves with the best available knowledge and take some simple, practical steps now to begin to incorporate resilience into MPA design and management. Here is a model, which includes four simple, practical steps that The Nature Conservancy and partners use to guide efforts to build resilience into coral reef management.

Description of the model: Simple first steps we can take (resilience may be more complicated)

First and most important, ***effective management is at the heart of resilience***. Managers need to protect reefs from direct threats such as boat and diver damage, pollution, sedimentation, and destructive fishing (including overfishing) and keep them healthy. The healthier the reefs, the more resilient the corals are, the greater the chance of successful recruitment, and the more likely they will be to bounce back after a catastrophic event. Enhanced recovery of reefs helps to sustain the many benefits for fisheries, tourism, livelihoods, and sustainable development. Additionally, managers must make efforts to include stakeholders in decision making. *Coral reef users*, like traditional fishers, dive operators, and other user groups, should be assisted to understand the principles of coral resistance and resilience to bleaching and should participate early in coral reef MPA selection and design. This will help to ensure clear understanding of the concept of reef survivability, strong grassroots support for conservation at the site, and effective partnership in management where appropriate.

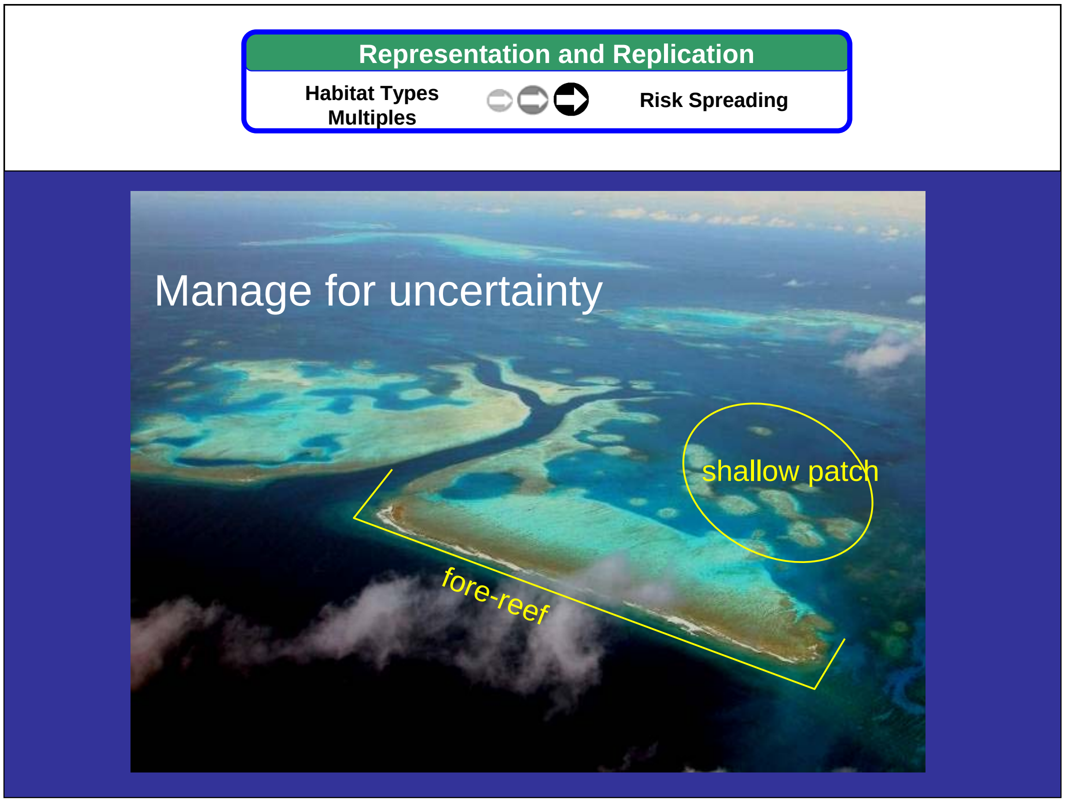
An important step is to ***reduce the risk*** of possible wrong decisions resulting from the uncertainty we face because of our incomplete knowledge of resilience and coral reef science. This step calls for managers to protect multiple examples of the full range of coral habitat types, including critical habitats of target species. Replication of each habitat type at multiple locations reduces the risk of any one type being totally lost during a major bleaching event or hurricane, for example. So, if any one coral community is lost, others remain to provide necessary larvae and help it to recover. Replication must incorporate both transport/stepping stone functions as well as ecological and biodiversity considerations (e.g., species and functional group representation, habitat representation, size). Managers will need to develop a good classification scheme of reef types and major reef zones, and categorize these by their functional groups and biodiversity.

It is also important to protect communities that are naturally positioned to survive global threats. Managers can identify and fully ***protect coral communities that resist bleaching*** because they are protected by such environmental factors as natural cooling, shading, screening, and any other factors that help corals become stress hardened as well as internal factors resulting from the genetics of the corals, zooxanthellae or microbes.. Good indicators of this include a high ratio of live to dead coral and a broad size/age frequency distribution that includes small colonies through intermediate sizes to large older ones. These refuges provide secure and essential sources of larvae to enhance the replenishment and recovery of reefs damaged by bleaching, hurricanes, or other events.

Connectivity is another important component of resilience. Some reefs may be sufficiently large to be self-seeding. Others may rely on reefs up current to provide the larvae they need for replenishment. Understanding how and where the larvae of corals and other reef species are distributed enables managers to identify source and sink reefs and to link these into a network of protected areas that is mutually replenishing. In this way, coral habitats that are damaged by bleaching or other causes can be repopulated by larvae from healthy reefs that are positioned up current.

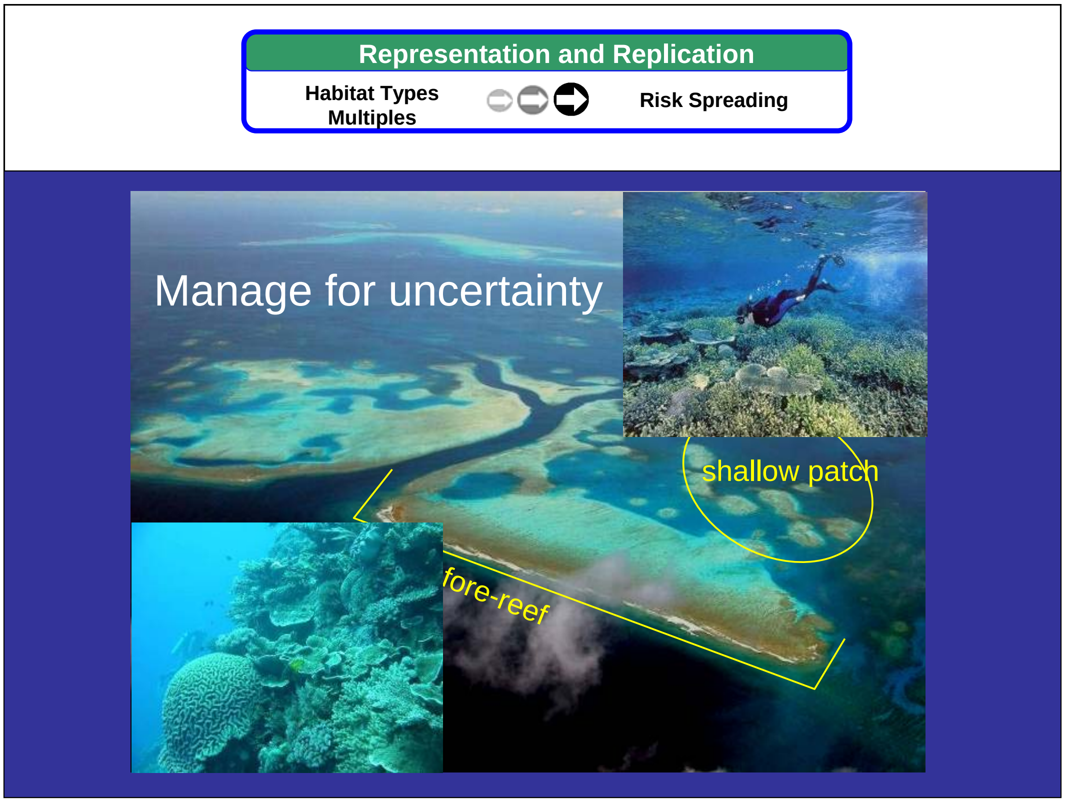
Connectivity should also be considered among reefs and neighboring habitats, especially seagrass beds, mangroves, and back-reef lagoons that provide important fish nurseries and nutrients, and watersheds and adjacent coastal lands, which are sources of freshwater, sediments and pollutants.

So, combining effective management with risk spreading, refugia, and connectivity provides guidance to managers on how to build resilience into coral reef conservation. How would we apply this knowledge to select and design coral reef conservation areas?



Our knowledge of resilience is still developing. We don't know all the answers, so we need to spread the risk of any decisions we make being the wrong ones. We do this by protecting samples of all major habitat types and at least three replicates of these – and we spread them out. This way we build redundancy into the system. If any catastrophic event takes out one of our reef types with its complement of biodiversity, others survive to help it recover. It is equivalent to diversifying your investment portfolio.

As an example, here are many different reef types – I've illustrated two with quite different species assemblages – sheltered patch reefs that are characterized by branching and table corals and steep fore reefs that have plate corals and boulders like this brain coral.



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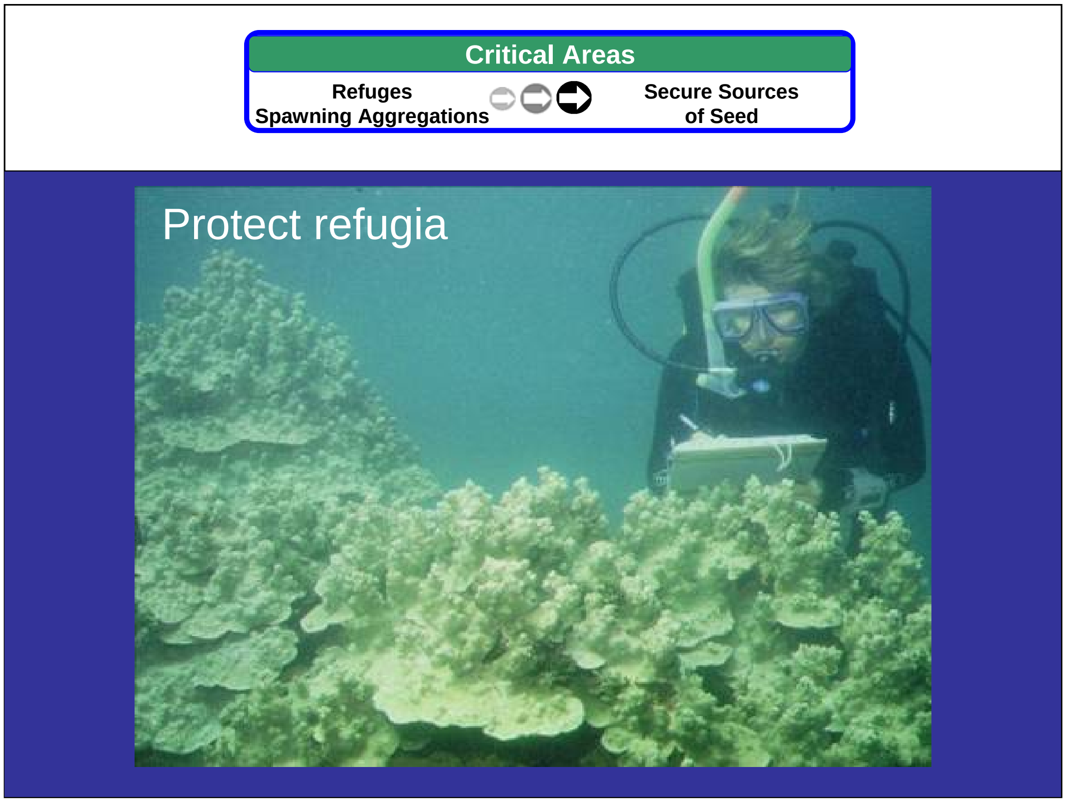


The largest mass bleaching happened in 1998 and was linked to higher than normal seawater temperatures – it was a global wake-up call. While the world responded by obsessing over the death and dying of corals, others focused on trying to understand why some corals lived, reasoning that this would provide us the key to focusing our investments on the survivors.

Now, more and more people are recognizing that not all corals respond equally to heat stress and there are even some coral communities that do not bleach at all or, if they do bleach, they recover quickly from it with minimal mortality. So, if we build our understanding of why some coral communities tolerate or avoid heat stress and bleaching, or survive it, and focus our efforts on these survivors, we have the foundations on which to build coral conservation programs that are designed to cope with climate change and its associated heat stress.

We found strong survival in the most unlikely places, such as cloudy inshore waters which act like shade netting to screen out the harmful rays of the sun and so protect the corals from the intense solar radiation that accompanies heating events. Conservationists have not usually looked for conservation areas in such places, favoring instead the clear waters over offshore reefs. The corals on reefs in cloudier or well shaded inshore waters provide refuges that seed the recovery of damaged reefs; and we learned that we need to pay more attention to these so-called marginal reefs as they hold the key to reef recovery and survival. This concept of protecting refuges is a key element in developing resilient MPA networks.

Connectivity

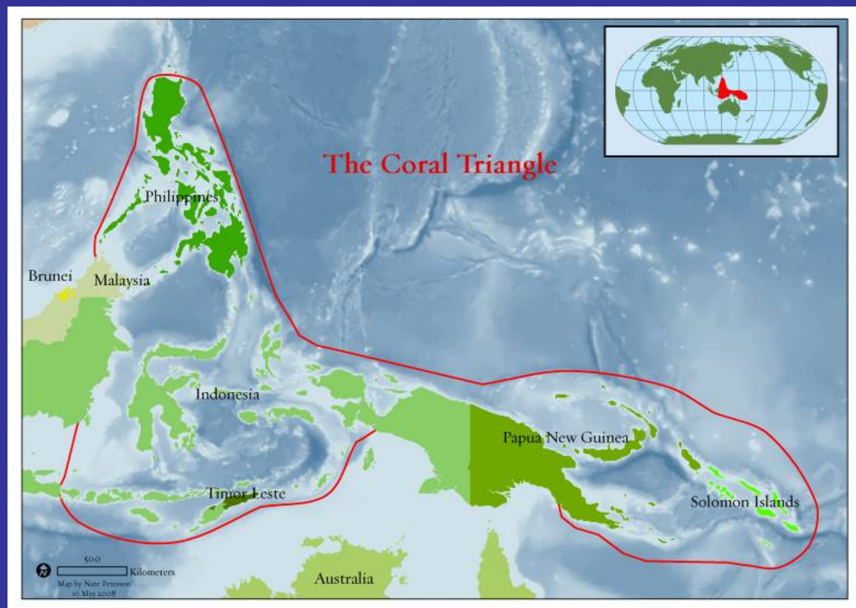
Transport **Replenishment**

Link with refuges – recovery

Also absolutely key is understanding how these refuges are connected to the more vulnerable sites that they seed and help to recover. Strong connectivity and the ability to recover quickly and thoroughly are also key pieces of our resilience model. We need to keep these avenues of connectivity open so that larvae can travel unimpeded from refuges to the damaged areas. This reef is a great example of strong connectivity and good local conditions to favor recovery. In 1998, the corals on this reef were essentially eliminated. Seven years later, this is what was found there. Near complete cover by living corals, many of which were over a half a meter across, and intermediate sizes too indicating good annual connectivity to a larval supply. A good and uninterrupted supply of larvae of all reef organisms is essential for strong recovery, So. We need to identify, understand and maintain the corridors of connectivity.

First and most important, ***effective management is at the heart of resilience***. Managers need to protect reefs from direct threats such as boat and diver damage, pollution, sedimentation, and destructive fishing (including overfishing) and keep them healthy. The healthier the reefs, the more resilient the corals are, the greater the chance of successful recruitment, and the more likely they will be to bounce back after a catastrophic event. Enhanced recovery of reefs helps to sustain the many benefits for fisheries, tourism, livelihoods, and sustainable development. Additionally, managers must make efforts to include stakeholders in decision making. *Coral reef users*, like traditional fishers, dive operators, and other user groups, should be assisted to understand the principles of coral resistance and resilience to bleaching and should participate early in coral reef MPA selection and design. This will help to ensure clear understanding of the concept of reef survivability, strong grassroots support for conservation at the site, and effective partnership in management where appropriate.

The Coral Triangle



This slide shows the location of the Coral Triangle – the global epicenter of coral reef biodiversity, development and persistence through the ages. The CT has 76% of the world's coral species and reefs that have survived previous climate changes to then repopulate surrounding areas and help establish reefs there when favorable sea conditions return. This is the area where many have invested most effort in developing and applying ways to climate-proof our investments in coral reef conservation. I will show how we did this in Kimbe Bay Papua New Guinea over toward the right hand side of the map.

Resilience in practice: Kimbe Bay, Papua New Guinea

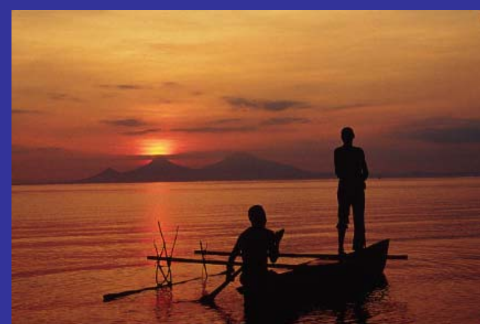
Large, well defined bay (140 x 70 kms)

Kimbe provides a great opportunity to a wide variety of marine habitats in close proximity, including mangroves, a range of coral reef types, deep oceanic waters and seamounts. Deep oceanic waters are recognized as a globally significant oceanic waters for toothed whales and pelagic fish

As of June 2008, most of these areas are also in great condition and of high conservation value.

Kimbe MPA network design objectives

- To maximize biological objectives by taking into account key biological and physical processes
- To maximize benefits and minimize costs to local communities and sustainable industries



We (TNC) had two sets of design principles:

-The biophysical principles that were aimed at minimising biological objectives by taking into account key biological and physical processes. Many of these were our resilience principles

-Socioeconomic that were aimed at securing food and income to coastal communities.

Since this talk is focusing on applying biophysical resilience principles, we only address the first one here. But please know that the socioeonomic principles play a key role in designing the network (See Kimbe Case Study for more info).

Kimbe MPA network design principles

1. Conserve representative examples of each habitat type

2. Aim to include a least 3 replicates and 20% of the area of each bioregion

3. Include special and unique areas including:
   - areas more resistant / resilient to coral bleaching
   - areas that support high species diversity

4. System wide approach that recognizes patterns of connectivity within and among ecosystems

5. Include entire biological units (e.g., whole reefs)
   - choose bigger over smaller areas

I would like to quickly run through and give you a feel for our design principles, to demonstrate how we aimed to apply the resilience principles, although I won't go through them all in detail.

Overall there were about 20 principles, of which these five capture the main points

Key areas that need to be strengthened and where additional research can help include developing reliable means to identify areas that are more resistance or resilient to bleaching. And cracking the conundrum (puzzle) of connectivity, which remains a huge challenge.

Kimbe MPA network management principles

1. Engage communities and get their support
   - use traditional management framework if possible
2. Keep reefs healthy through effective management
   - healthy reefs more likely to survive major impacts
3. Consider both sea- and land-based threats

Because of capacity constraints in PNG generally and Kimbe in particular, we completed the scientific design of the network first and now are embarking on the slow task of communicating with coastal communities, explaining the need for conservation, the process of network design and need to address climate change issues, how the network approach requires collaboration among different clans for the greater good of the whole. We are engaging the oil palm and tourism operators intimately in these discussions. We will then be able to focus attention on addressing the management issues directly through various partnerships.

Kimbe MPA network design process

- 02/04-07/06
- 1st science workshop → objectives, boundaries, design principles
- Priority research → minimum data for design
  → best data in GIS layers

- 2nd science workshop → GIS data layers revised
- MARXAN analysis → network design options

- 3rd science workshop → scientific network design

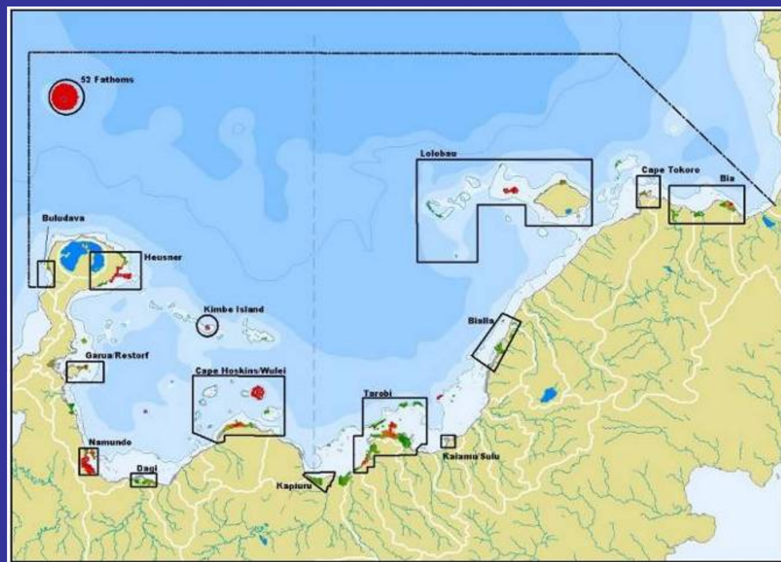
- 07/06-present
- Finalize, negotiate network design with stakeholders
- Implementation

Getting the science right and completing essential research has taken 2 ½ years. The first scientific workshop produced the foundations for building the network and laid out the priority research needs.

The second workshop reviewed and added expert knowledge to refine the data layers so that we could proceed with MARXAN analysis leading to various MPA design scenarios. The optimum scenario is one that was determined by scientific resilience criteria and balances this with various cost options.

We are now in the implementation phase and have several communities agree to establish MPAs towards the network.

Kimbe resilient MPA network design



We applied the resilience principles I've described in Kimbe Bay, PNG, to help design the world's first MPA network specifically to be resilient to climate change.

The design captures reefs with high biodiversity, high coral cover and areas known to be resistant to bleaching (the refugia). We spread risk by including at least three examples of all different reef types (inshore and offshore reef systems of different kinds, like the inshore fringing and patch reefs seen here, as well as from both the east and west sides of the bay because they have different levels of exposure to waves and currents and different assemblages of coral and fish species) and we spread them out.

The design addresses connectivity too by the size and spacing of the MPAs: the MPAs are large enough to be self seeding for the species whose larvae do not move far and are spaced close enough for the longer distance dispersers.

Kimbe resilient MPA network design

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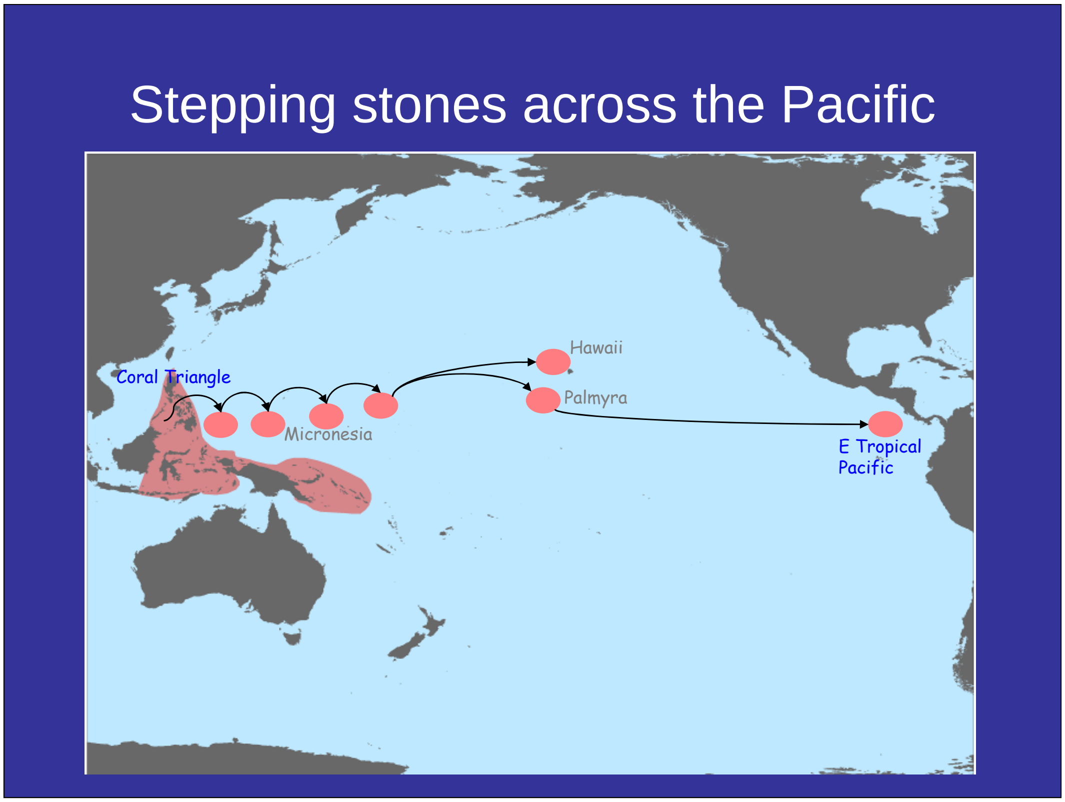

Let's look at how we have taken our concepts of refugia and connectivity to different spatial and time scales. The Coral Triangle is a global refuge for coral reef communities, a natural place to anchor coral reef conservation in the Indo-Pacific. It is connected along the flow of ocean currents with other reef systems across the Pacific. TNC's goal is to help our partners establish resilient marine protected area networks through Micronesia across the stepping stones of the Pacific to Hawaii, which is an end point in coral reef distribution and relies heavily on imported larvae for the survival of its reef based communities, and to Palmyra Atoll, which is the last stop and jumping off point for larval connectivity to the west coast of Central America.

A Leadership Role for Your Country

Your Government policies can:

Support resilience research & field applications

Ensure that nature-based adaptation is:

- Integral to CC adaptation & development programs
- Adopted internationally as a viable, good investment
- Key component of international framework on CC

Your government can play a major global leadership role in addressing climate change impacts of coral reefs. Here's how:

Securing sufficient budget appropriations to support research and applications:

- especially for coral reef research, monitoring, and conservation programs
- Incorporating climate change concerns into land-use plans, e.g., building buffer zones around vulnerable coastal habitats so that beaches can move and mangroves can expand inland as sea level rises; not permitting development in dynamic coastal zones (dunes systems, accreting coastlines), establishing coastal set-backs and preventing hardening of shorelines)

Also, in the policy and development assistance arena, by ensuring that nature-based adaptation as opposed to infrastructure based adaptation:

- Is a central and substantive component of development assistance through loans and grants from international or bilateral development aid agencies, the World Bank, and the Global Environment Facility (GEF)
- Is adopted internationally as a viable and good investment
- Is included as a key component of any international frameworks on climate change

If the perils of our time are unprecedented, then so are the opportunities. – Anonymous

Building resilience into the coral reef conservation programs of your country starts with you and your work, these are the key ingredients of coral reef survival in our rapidly changing world. Good luck with your work and remember, everything you do helps.