Coral Reefs, Climate Change and Resilience

An Agenda for Action from the IUCN World Conservation Congress in Barcelona, Spain

David Obura & Gabriel Grimsditch

IUCN RESILIENCE SCIENCE WORKING GROUP PAPER SERIES - NO 6

IUCN Global Marine Programme

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The IUCN Global Marine Programme provides vital linkages for the Union and its members to all the IUCN activities that deal with marine issues, including projects and initiatives of the Regional offices and the six IUCN Commissions. The IUCN Global Marine Programme works on issues such as integrate coastal and marine management, fisheries, marine protected areas, large marine ecosystems, coral reefs, marine invasives and protection of high and deep seas.

Acknowledgements

The workshops and publication of this document were made possible by a grant from the John D and Catherine T. MacArthur Foundation to the IUCN Climate Change and Coral Reefs working group.

Editors

David Obura	Director, CORDIO East Africa/Chair, IUCN Climate Change and Coral Reefs working group
Gabriel Grimsditch	IUCN Global Marine Programme/Climate Change and Coral Reefs working group

Contributors

Tundi Agardy	Director, Marine Ecosystems and Management (MEAM)
Kent Carpenter	Director, Global Marine Species Assessment. Professor, Old Dominion University
Alison Green	Senior Marine Scientist, Tropical Marine Conservation Program, Asia Pacific Conservation Region, The Nature Conservancy
Lynne Hale	The Nature Conservancy
Jennie Hoffman	Senior Scientist, EcoAdapt
Dan Laffoley	Chief Scientist's team, Natural England
Ramon De Leon	Bonaire Marine National Park (STINAPA)
Nadine Marshall	Sustainable Ecosystems, CSIRO
Paul Marshall	Director, Climate Change, Great Barrier Reef Marine Park Authority
Rodney Quatre	Head of Research, Seychelles Centre for Marine Rsearch and Technology – Marine Parks Authority (SCMRT-MPA)
Enric Sala	Fellow, National Geographic Society; and Researcher, Spanish National Research Council
Robert Steneck	Professor of Oceanography, School of Marine Sciences, University of Maine
Greg Stone	Vice President, Global Marine Programmes, New England Aquarium/Phoenix Islands Protected Area.
Stephanie Wear	MPA Scientist, Global Marine Team, The Nature Conservancy

Cover Photography

Front cover: Artisanal fisherman in Pemba, Tanzania. © Cheryl-Samantha Owen, Save Our Seas Foundation

Back cover: Kenya Wildlife Service rangers and scientists patrolling Mombasa Marine Park after conducting coral reef resilience surveys. © Cheryl-Samantha Owen, Save Our Seas Foundation

Coral Reefs, Climate Change and Resilience

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Published by: IUCN, Gland, Switzerland

Citation: David Obura & Gabriel Grimsditch (2009). Coral Reefs, Climate Change and Resilience – An agenda for action from the IUCN World Conservation Congress. October 6-9 2008. 44 pages.

ISBN: 978-2-8317-1158-4

Available from:
IUCN Global Marine Programme, International Union for the Conservation of Nature,
Rue Mauverney 28, 1196 Gland, Switzerland.
Tel: +41 22 999 02 17 Fax: +41 22 999 00 25
E-mail: marine@iucn.org or Gabriel Grimsditch; ggrimsditch@iucnus.org

CORDIO East Africa (Coastal Oceans Research and Development – Indian Ocean)
9 Kibaki Flats, Kenyatta Beach
P.O.BOX 10135, Mombasa 80101, Kenya
Web: www.cordioea.org
David Obura; dobura@cordioea.org

This publication is available as a download from the IUCN Global Marine Programme website at the following address: http://www.iucn.org/cccr/publications/

Printed in Switzerland on chlorine-free paper from FSC-certified forests.

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David Obura & Gabriel Grimsditch

IUCN Resilience Science Group Working Paper Series – No 6

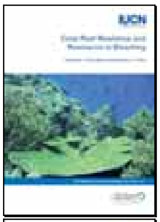
About the IUCN Climate Change and Coral Reefs Marine Working Group

The IUCN Climate Change and Coral Reefs Marine Working Group (formerly the IUCN Resilience Science Working Group), focused on coral bleaching, resilience and climate change, was established in 2006 by the Global Marine Programme of IUCN on a 3-year grant from the John D. and Catherine T. MacArthur Foundation. The goal of the working group is to draw on leading practitioners in coral reef science and management to streamline the identification and testing of management interventions to mitigate the impacts of climate change on coral reefs. The working group consults and engages with experts in three key areas: climate change and coal bleaching research to incorporate the latest knowledge; management to identify key needs and capabilities on the ground; and ecological resilience to promote and develop the framework provided by resilience theory as a bridge between bleaching research and management implementation.

One of the outputs of this group was the setting up of a website that provides links to projects, events, partners and publications.

For more information, see http://www.iucn.org/cccr/publications/

This publication is the 6th in a series of publication on management tools to promote resilience in marine ecosystems. The other five available from IUCN's Global Marine Programme are listed below:



Coral Reef Resilience and Resistance to Bleaching
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Elizabeth Mcleod and Rodney V. Salm
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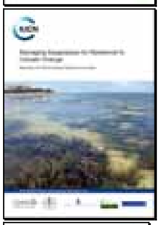

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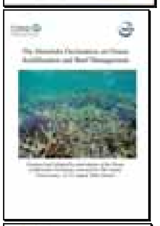

The Honolulu Declaration on Ocean Acidification and Reef Management.
McLeod, E., R.V. Salm, , K. Anthony, B. Causey, E. Conklin, A. Cros, R. Feely, J. Guinotte, G. Hofmann, J. Hoffman, P. Jokiel, J. Kleypas, P. Marshall, and C. Veron.
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Resilience Assessment of Coral Reefs. Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress
David Obura and Gabriel Grimsditch
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Executive Summary – Priorities for Action

Three linked workshops were held at the 4th IUCN Conservation Congress in Barcelona, Spain, in October 2008. The common theme among the workshops was the use of resilience approaches in conserving coral reefs. One workshop was focused on the science of resilience assessment, the second on applying resilience principles in Marine Protected Area Management, and the third on policy tools and approaches that can support resilience-based conservation. The workshops were organized by CORDIO (Coastal Oceans Research and Development in the Indian Ocean) and The Nature Conservancy (TNC), assisted by the IUCN Climate Change and Coral Reefs working group (CCCR).

This report highlights new themes for action identified by presenters in the workshops by collating suggestions and recommendations into one document as a platform for further action by organizers and participants. A major outcome of the sessions was the drafting and adoption of a formal resolution on supporting resilience-based management of coral reefs and other marine organisms, calling on IUCN to adopt and promote these approaches in its 2009-12 Work Programme, and for other organizations, countries and partners to do the same (Resolution 4.080).

Resilience as a framework for action

Resilience is a concept drawn from ecological theory that has cross-over value to considering social and economic contexts, the interdependence of people and the environment, and how perceptions, values, management decisions and political decisions can influence these. Thus it has great potential to facilitate bringing together objectives from the fields of conservation and sustainable development to both conserve ecosystem health and alleviate poverty particularly in natural resource-dependent communities.

With the overarching threats of climate change and global population growth, it is an essential task to marry human and biodiversity objectives to make them compatible and mutually sustaining. Coral reefs play a key role as a canary in the coal mine, highlighting impacts of both climate change and increasing human population pressure. This is also true of efforts to conserve and manage coral reefs, where these lessons can serve a much broader constituency to identify how to conserve and manage other ecological and human systems faced with similar challenges.

Accordingly, this Executive Summary highlights the linked, holistic and cross-cutting actions that need to be taken in science, management and policy circles to minimize the impact of climate change on coral reefs an other ecosystems c, and thereby on the 100s of millions of stakeholders dependent on coral reefs globally.

Priorities for science

To operationalize resilience for science and management – a ***compartment model for ecological resilience*** is used that then enables the identification of key drivers of resilience. The model is simple enough to facilitate communication but robust enough to carry research hypotheses, be updated as new findings become available, and make management recommendations that can be tested and assessed for efficacy. The same model can be adapted to other ecosystems and to incorporate human and social components.

For coral reefs, ***strong drivers of resilience***, in the context of climate change, include:

- coral community composition and dynamics – the identity of the keystone species determines responses to the primary threat of seawater warming;
- habitat and other environmental factors that affect ecological diversity and complexity, as these are the classical controls on coral community composition and dynamics;
- algal community dynamics and herbivore populations, as algae are principal competitors to corals, and algae are themselves controlled by herbivory;
- connectivity at a relevant ecological scale for ecological recovery and maintenance of genetic diversity;
- human actions that affect any of these strong drivers negatively (e.g. fishing reduces herbivore populations and removes control of algae; pollution reduces water and environmental quality) or positively (e.g. effective fisheries or Protected Area management protect or can even restore the strong drivers).

Other factors may be only weak drivers, or neutral, but may have value as ***indicators of resilience*** e.g. obligate coral feeders are an indicator of the amount of coral and the complexity of habitat and nutrition they provide. Using a diversity of indicators in assessing resilience and impacts is useful in capturing the complexity of ecosystem dynamics and to capture unexpected findings that may highlight key aspects of resilience.

Greater investments need to be made in ***using research findings for adaptive management***, as well as for generating ***adaptive actions***, such as by resource users. Adaptive management and policy-making should become increasingly operationalized in a changing climate where new threats are continually becoming apparent (e.g. recently ocean acidification), and research findings from resilience programmes should be assimilated quickly into decision-making processes. With their explanatory value across ecological and social dimensions, resilience concepts can help link scientific findings to adaptation actions.

Complementary to assessment of ecological resilience, ***tools for quantifying social resilience*** are needed that can link ecological measurements to resource use practices and thence to adaptive actions. Resilience concepts can facilitate this by reducing barriers across the disciplines, and facilitating comparison and interpretation. The goal is to be able to measure changes in peoples' vulnerability to climate change and ecosystem degradation. If social benefits can be quantified in this way, then access to adaptation and carbon funds will be improved to finance the growing need there will be for social action.

Priorities for management

Enhancing the development and use of ***tools for management***, based on resilience, is a key priority. To date, resources such as the R2 toolkit and Reef Resilience Assessment method have been developed, and additional tools are needed to further assist managers. Networking and communications among managers and between them and scientists, other professionals and stakeholders are key strategies for expanding the acceptance and use of resilience principles in management.

Of critical importance for management is the establishment of ***supportive policy for adaptive management***, focusing on flexibility, responsiveness to change and resources to enable action. Resilience concepts can provide principles on which to base policy, from which options for interventions, priority setting mechanisms and communication strategies can be developed.

Economic and financial arguments, and public education, will ultimately be the factors that will drive decision makers, and resilience concepts provide a means to translate the value of individual reef components in the larger context. For example, a herbivorous fish that contributes to maintaining overall ecosystem health is worth more in the water, providing its function daily, attracting tourists and reproducing, than providing a single meal.

Priorities for policy

Policy development is urgently needed to consolidate and support recent advances in resilience science and resilience-based management, and pave the way for new discoveries. ***Urgent policy actions*** that are needed all relate to development of frameworks for management and adaptation actions that are responsive to climate change. These include:

- policies that ***facilitate managers*** to take adaptive action;
- the development of ***management frameworks that are flexible*** and can respond to challenges;
- increased use of ***holistic/multisectoral approaches***, such as Ecosystem-Based Management (EBM) and Integrated Coastal Zone Management (ICZM) and Participatory approaches to rural development;
- policies that ***support social resilience*** by reducing peoples' vulnerability in the face of change, particularly with respect to natural resource-based livelihoods.

Policy arenas that can be increasingly used to serve these purposes, and to build consensus for action include:

- ***technical/expert consensus statements***, particularly targeted at key needs/geographic areas where they can support action, and by expert bodies with the necessary credibility;
- ***socio-economic valuation*** and estimation of the ***costs of adaptation and delayed action***, to internalize real costs of climate change in the decision-making process and resolve the market failures that currently externalize environmental costs;
- improved ***communications strategies and tools***, particularly targeting policy and non-environmental sectors, such as annual report cards updating progress;
- making the appropriate links to climate change in ***international conventions and institutions*** under which governments and other bodies are committed to action.

A canary in the coal mine. From a communications perspective the story of coral reefs is particularly powerful and clear, being one of the first ecosystems to clearly show climate change impacts, and being well understood, highly visible and with star-appeal. As a result, learning on resilience-based science, management and policy for coral reefs has broader value globally for other ecological and human systems. The coral reef message should be used broadly, to influence public and policy opinion on climate change, particularly on the value of the holistic resilience approach in identifying preemptive action.

Bleached Acropora coral on the Great Barrier Reef. Bleaching is a phenomenon resulting from high temperature stress. The coral expels its symbiotic micro-algae and is left in a weakened state, prone to disease and mortality. Bleaching events such as the one depicted are expected to increase in frequency and intensity because of global climate change. By Paul Marshall, Great Barrier Reef Marine Park Authority.

Findings from coral reefs should be more efficiently ***incorporated into the UNFCCC*** process by improving reporting to the Intergovernmental Panel on Climate Change (IPCC). Further, through key policy advisors in key countries active in the United Nations Framework Convention on Climate Change (UNFCCC), to engage more effectively in the setting of agendas and topics for consideration during the UNFCCC Conference of Parties (COPs).

The global conservation community needs to take a stronger hand in raising the profile of climate change and the signature value of coral reefs. IUCN, as the convenor of many different conservation and development practitioners globally, has a unique role to play here. Hence, a resolution to strengthen the role of IUCN in ***promoting resilience-based management and conservation*** of coral reefs was formulated and adopted by the Assembly at the 4h World Conservation Congress. The resolution can be used by IUCN, its members and other parties to promote actions supporting resilience-based adaptation to climate change, for coral reefs and other systems.

IUCN Resolution 4.080. Mobilizing action to build resilience

Full title: Mobilizing action to build resilience and assist adaptation to climate change of coral reefs and marine ecosystems and people that depend on them.

RECOGNIZING the key role that oceans play in sustaining life on our planet;

ALARMED at the multiplying threats to marine biodiversity, health and the livelihoods of coastal people through the major climate-change threats of rising seasurface temperatures, and the impending threat of ocean acidification;

FURTHER ALARMED at the accelerating rate of degradation of marine ecosystems such as coral reefs, mangroves, and marine resources, due to activities such as overfishing on a global scale including Illegal, Unregulated, Unreported (IUU) fishing and the use of destructive fishing methods, which according to the UN Food and Agriculture Organization (FAO), resulted in more than 75% of the world's fish stocks being fully exploited or overexploited (or depleted and recovering from depletion);

NOTING findings of the Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report* on the vulnerability of marine ecosystems, especially coral reefs, to climate change and the need for more marine science contained in the IPCC assessments;

RECALLING Resolution 2.55 *Millennium Ecosystem Assessment* adopted by the 2nd IUCN World Conservation Congress (Amman, 2000) and Decision VII/5 of the 7^{th} Meeting of the Conference of Parties to the Convention on Biological Diversity (CBD COP7, Kuala Lumpur, 2004) that describe the challenge of sustaining coral-reef and marine ecosystems;

FURTHER NOTING the IUCN Members' Report to the International Coral Reef Initiative (ICRI) at the ICRI General Meeting in Tokyo, Japan, 2007, that details IUCN activities in support of coral-reef conservation in the face of climate change;

AWARE that the *IUCN Programme 2009-2012* identifies actions to build resilience in coral-reef and mangrove ecosystems;

FURTHER NOTING that participants in the IUCN World Conservation Forum (Barcelona, October 2008), called for action by the global conservation community to link science, management and policy to increase the resilience of marine ecosystems and the people that depend on them; and

WISHING to consolidate and support actions to build the resilience of marine ecosystems and help these systems cope with climate change;

The World Conservation Congress at its 4th Session in Barcelona, Spain, 5-14 October 2008:

1. CALLS ON IUCN's members to bring to the attention of the IPCC and the United Nations Framework Convention on Climate Change (UNFCCC), including its Parties, the need for:

(a) more marine science to be incorporated in IPCC assessments; and

(b) the development of adaptation measures to increase the resilience of coral reefs and other marine ecosystems, and the people that depend on them;

In addition, the World Conservation Congress, at its 4th Session in Barcelona, Spain, 5-14 October 2008, provides the following guidance concerning implementation of the *IUCN Programme 2009-2012:*

2. REQUESTS the Director General and the IUCN Commissions to:

(a) expand resilience work on coral reefs and mangroves to other marine ecosystems;
(b) promote actions and linkages by the Secretariat, members and partners that improve science, management and policy relevant to sustaining coral reefs and marine ecosystems and the people that depend on them; and
(c) promote the development of awareness and adaptation actions in support of sustainable livelihoods and ecosystem-based management.

Full text can be obtained from: http://www.iucn.org/congress_08/assembly/policy/

The sponsors of the motion were:

- CORDIO East Africa
- The Nature Conservancy
- Conservation International
- Project Aware Foundation
- Save Our Seas Foundation
- The Cousteau Society

Workshop discussions and findings

Coral reef ecosystems are under unprecedented threat from a combination of local and global stresses. At stake are the livelihoods and wellbeing of hundreds of millions of people, and ecosystem goods and services worth billions of dollars. Understanding the nature and strength of human dependency on coral reef resources and implementing effective strategies to build resilience across ecological and social systems is critical to alleviate the 'coral reef crisis'. While there remain large gaps in our understanding of the problem and potential solutions, policy development and implementation lags behind current knowledge. This workshop aims to explore science-policy and management-policy gaps to identify policy approaches and tools that can support efforts to build resilience of coral reefs in the face of climate change.

Resilience is an emerging paradigm for understanding and managing complex ecosystems and the interactions between ecosystems and the people that depend on them. With continuously increasing human population pressures and changes in the earth's climate, natural resource managers face an urgent need to better understand how the world is changing, from local to global levels, and how to develop meaningful management strategies to cope with change and maintain natural processes. This need is particularly critical for coral reefs, which are highly complex and diverse systems and vital to the welfare of large human populations throughout the tropical world, and among the most vulnerable ecosystems to global changes.

Resilience definitions.
For discussion in the workshop sessions, and for consistency across science, management and policy issues, resilience was defined as ***"the ability of an ecosystem to cope with change or to recover to its original state following a disturbance"***.

'Resistance is used here in the narrow sense of corals' ability to resist bleaching and mortality during a high-temperature stress event.

Assessing reef resilience

The purpose of discussion in this first session was to relate the science of resilience to its use in management and policy frameworks.

A resilience framework for assessment

The IUCN-CCCR resilience assessment approach represents an attempt to operationalize this in a monitoring/assessment context, thus provides a useful platform for this exercise. The presentations covered general evidence for resilience and the key drivers that maintain it, how we have developed assessment methods to measure some key components of resilience, and linkages to social resilience. To be useful in understanding reef resilience in management and policy settings, it is critical to simplify the complex dynamics and components of reef ecosystems into a minimum set, and to specify ways to measure these and interpret the measurements simply and reliably.

Discussion circled around the need to distinguish among the diversity of factors, species and compartments that make up a coral reef and associated ecosystems. As currently understood, the primary compartments in the coral reef that are amenable to visual assessment measurements can be simplified to three parts (fig. 1), namely corals, algae and fish/consumer functional groups. In order to understand community dynamics, in addition to having information on these groups, it is important to know;

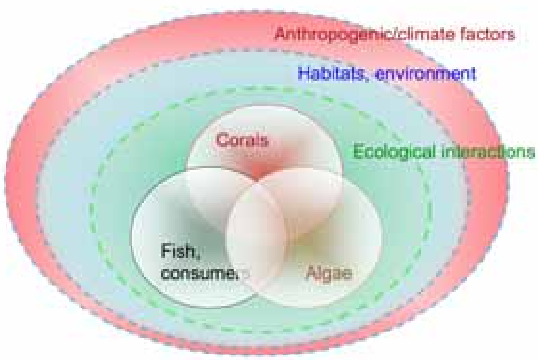

Fig. 1. Resilience compartments model, coral

1) the ecological interactions that drive dynamics within and among these groups, and 'strong interactions' that influence them from other compartments;
2) habitat and environmental influences that directly affect these compartments and the interactions between them; and
3) external drivers, including anthropogenic and climate factors.

Our understanding of a healthy ecosystem is that the above compartments and processes are in balance, whether this is in equilibrium or driven by stochastic processes; i.e. that there is long term stability of the system and an ability to cope with change and maintain internal processes. This conforms to the definition of – i.e. resilience is the ability of an ecosystem to cope with change or to recover to its original state following a disturbance (see p. 6). In distilling scientific knowledge into key concepts that can be used in management/policy circles and measured in an assessment framework, we must:

- define critical compartments and processes, how they are measured, and how to interpret the measurements;
- identify drivers of resilience along multiple dimensions. Key dimensions are 'good' vs. 'bad' drivers (ie. that maintain/strengthen resilience vs. those that undermine/weaken the system, respectively), or slow vs. fast drivers (i.e. in terms of rates of action). How these act on the critical compartments and processes must be specified, and measurements designed that can at least indicate positive/negative impacts on key resilience compartments and processes;

In considering the above, it is important to note that both pattern (state) and process (function) indicators and variables may be useful for measurement and interpretation. Both may be affected by drivers of resilience. Finding an effective way to describe and communicate past, present and future states and processes, based on the findings of surveys, will be essential to using the information in management and policy contexts.

Researchers measuring coral size class in a shallow lagoon at low tide as part of an IUCN coral reef resilience assessment. This innovative method helps us understand and quantify the most important factors driving coral reef resilience to bleaching. By Cheryl-Samantha Owen, Save Our Seas Foundation.

Drivers of resilience

In the context of climate change, reef degradation and phase shifts between alternate states of coral reefs, the presentations and discussion specified a set of strong drivers that influence the reef community (fig. 2). These drivers may act from one reef compartment to another (e.g. fish to algae), or across different levels (e.g. anthropogenic factors to corals). The role of the latest science in identifying the strongest and most active drivers, and which may change under different conditions and in different locations, is paramount.

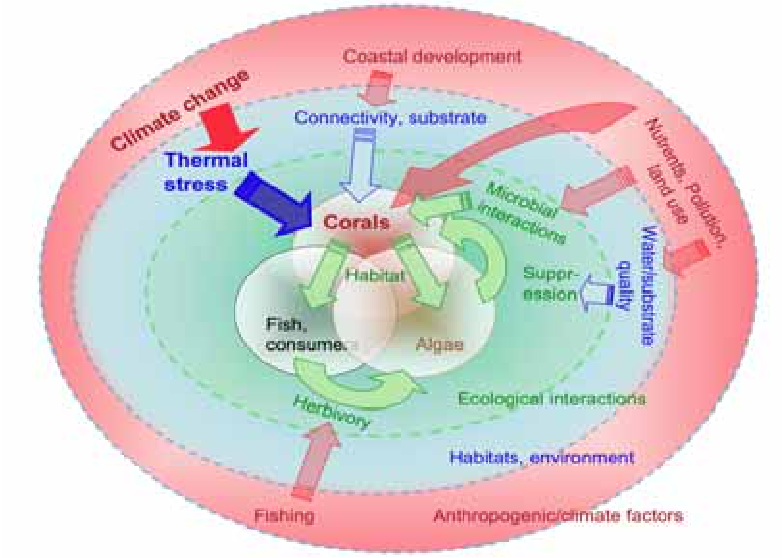

Fig. 2. The primary focus of discussion is the effect of climate change on thermal stress on corals (in bold). However this is affected by many other processes. A resilience framework helps identify the strong drivers (arrows) that maintain reef health and minimize vulnerability to climate change impacts.

Thermal stress. This is the primary driver of climate change-induced stress to coral reefs at the moment, and is the primary focus of the current debate. The primary influence of thermal stress is affected by environmental factors that affect water temperatures, such as cooling by upwelling and water column mixing. Synergistic stress by light is affected by factors that reduce the interactions between light and thermal stress, such as by turbid water. Finally, biological factors are important, such as the intrinsic stress resistance of corals or zooxanthellae, and acclimatization over time to thermal and general stress.

Physical/chemical factors. The physical/chemical environment is a key determinant of resilience, for example in aspects such as nutrient levels and substrate type. Research results do not unequivocally show the influence of nutrients or other physical factors in all cases – e.g. addition of nitrogen to some reefs/experiments results in eutrophication while in other cases it does not. It may be that local levels and adaptation need to be considered rather than absolute levels. In this case, changes from historic conditions are more important to know than simple measurements of current conditions. The complexity of interactions and compartments that relate to water quality, nutrients and microbial activity (fig. 4) precludes simple explanations. Additionally, physical processes affecting circulation around bays, headlands, and other features may fundamentally affect other physical and ecological processes, and these differences must be considered when establishing underlying conditions.

Herbivory is a key mediator of coral-algal dynamics and competition, with a strong influence on the recovery of coral communities following coral mortality where space is taken over by algae. Interactions with algae, such as competition or microbial enhancement may also affect the susceptibility of corals to bleaching. Herbivory itself is a diverse function, and a number of different functional groups are recognized. The diversity of species and of their vulnerability to stresses strongly affects how robustly each functional group contributes to reef resilience. Fish are the primary taxonomic group controlling herbivory, though under degraded conditions, other groups become important.

Connectivity. Currents disperse coral larvae enabling re-seeding of impacted reefs from refuge populations of hard corals. Current understanding indicates short distances are the most relevant, on the order of 10s of km, for effective re-seeding, much less than previously expected. Connectivity provides many other functions as well, such as in the provision of ecosystem services, such as of ecological interactions between adjacent reefs (vagile predators/herbivores), linked habitats (complex life cycles), and others. In the broader sense, connectivity includes factors such as available substrate and successful settlement of larvae.

Anthropogenic factors may change any of the above compartments in the figure, and drivers listed above. For example, environmental factors may be altered such as by coastal development, and this may alter key drivers of resilience, such as circulation that affects thermal stress. Similarly, fishing may affect the balance and actions of herbivore functional groups. Adding complexity to the role of nutrients and physical/chemical processes, anthropogenic alterations of water and substrate quality may have very complex impacts on reef processes (fig. 2).

The key threat considered here is climate change, however other major threats could fit into the above resilience model in place of thermal stress. The methodology could be adjusted to deal with other important threats as needed at individual sites.

Other points of importance included the following:

- less is known about drivers of reversals in phase shifts, such as of returning algal communities to coral reefs. These may be mediated by actors or processes relatively dormant or inactive under normal reef conditions, termed 'sleeping functional groups'. The importance of an open approach to monitoring and assessment, and of reef values/compartments to maintain and monitor is therefore essential.
- The role of other strong drivers, such as of pests such as the crown of thorns seastar, *Acanthaster planci* – these may vary in importance geographically and over time, and may be both indicators and drivers of resilience. Again, assessment and management systems must remain open to incorporating their effects where appropriate.
- The difference between slow and fast drivers of resilience is important, as some factors may cause small increments of change over a long time (e.g. pollution levels) while others cause large increments over a short time (e.g. mass bleaching event). These may play different roles at different times, and particularly affective phase shift reversals.

Indicators of resilience

Due to the great complexity of coral reefs, there are a number of factors that may be indicators of resilience, i.e. their presence is conditional on a healthy resilient ecosystem, as opposed to them being actual drivers of resilience. While there can be debate on the degree to which some may be drivers or indicators (or both), classic indicators incorporated into assessment methods include:

- Diversity of various taxa, including key drivers such as corals and fish, and of other groups such as fish/invertebrates resident in corals.
- Carnivores and piscivores, the top predators are the first to be targeted by fisheries, thus their presence is an indicator of extraction. Because of their function passing energy and biomass through food chains, top predators may also play a strong driving force in resilience and maintenance of reef health.
- The diversity and abundance of associates dependent on corals, such as of obligate feeders (e.g. butterflyfish) and resident fish and invertebrates in branching corals.

Left photo A degraded reef with low resilience to disturbance. Although recruitment on to the dead coral framework is occurring, coral recruits such as this Acropora are quickly predated, giving little chance for the coral community to recover. By Jerker Tamelander, IUCN Global Marine Programme.

Right photo: This reef had been heavily impacted by a bleaching event, but exhibits robust recovery of branching and plating corals and the potential for high resilience to disturbance. By Jerker Tamelander, IUCN Global Marine Programme.

Monitoring resilience

Recommendations and comments that relate to improving the science and assessment of resilience were made, and summarized below. In addition, discussion covered using the knowledge for ACTION – such as in identifying management actions that alter the drivers of resilience (fig. 2) to achieve the desired outcome of increased reef health. In addition, with the broader focus of sustainable resource use and interactions between people and reef environments, using knowledge about resilience drivers to identify ADAPTATION actions by people, that both maintain/increase reef resilience AND provide sustainable ecosystem goods and services to dependent people.

Due to the complexity of interactions on coral reefs, resilience assessments are most powerful where considerable monitoring information has already been collected and/or research has already identified key aspects of local reef ecology and use. These provide a critical historical and temporal context for interpreting the state and process indicators quantified in the resilience assessment.

Management to minimize threats and maximize resilience can take many forms, depending on the processes being targeted by interventions (fig. 2). Thus reserves can mitigate some stresses (e.g. fishing), but classically have not dealt with others (e.g. thermal stress), and may even increase others (e.g. tourism and coastal development). Thus a holistic view of threats and resilience can be used to broaden the scope of management interventions under consideration to improve the efficacy of mitigating climate threats as well as others.

The analysis of strong resilience drivers also provides opportunities to prioritize management actions, and determine which ones are amenable to management. Through site-based assessments, management can be tailored to individual locations and the pressures they face.

Social resilience and adaptation

Applying the resilience framework to the broader context of social resilience and dependence on reef ecosystems can greatly facilitate actions to enhance and maintain ecological resilience. Social and ecological resilience frameworks show striking similarities, related to flexibility and diversity at the system level. Importantly however, social systems have the added ability to anticipate the future and plan for it, greatly increasing the opportunities to increase both ecological and social resilience by ADAPTING to changing conditions under climate change.

This is an essential concept for moving towards effective “climate adaptation” for people vulnerable to climate change. Because the resilience framework dissects the ecological and social systems into strong and weak drivers, it provides opportunities to explicitly select options for management (intervention, adaptation) that focus on key drivers but that are set in a holistic context, and act in a predictable way for both ecosystems and people. This also reflects a broader interpretation of the concept of ‘adaptive management’, by involving a more explicit consideration of the additional social components that affect resilience. These relate to perceptions of ecological and material value, aspects of psychological, cultural and social values, the acceptability of potential interventions and aspects of social and political organization. Thus options for adaptation are firmly grounded in ecological reality, but go far beyond this to what is feasible in social terms.

Kenyan fisherman returning from a day's fishing on his traditional ngalawa catamaran. Poor coastal fishing communities that depend directly on coral reef resources are often the most vulnerable to climate change. By Cheryl-Samantha Owen, Save Our Seas Foundation.

Enhancing resilience-based management

Since 2004, TNC, in partnership with WWF, WCS, IUCN, GBRMPA, CORDIO, and NOAA, has led an effort to train coral reef managers on methods of building resilience into the design and management of MPAs and networks in the face of global climate change. Regional trainings were based on the Reef Resilience Toolkit published in 2004 and were held in the Caribbean, Southeast Asia, Western Pacific, Western Indian Ocean, and South Asia. Over 140 managers from over 40 countries have participated. Since the workshops, managers have been working to build resilience into their network designs, zoning plans, monitoring, and other management activities. As work has progressed, so have the science and information available to managers. In mid 2008, the science and recommendations were updated and have been packaged into a new version of the Reef Resilience Toolkit. This new suite of Reef Resilience Resources is available at http://www.reefresilience.org/.

The workshop discussions highlighted lessons learned in applying resilience as well as discussion of challenges and new directions for the application of resilience in tropical marine resource management.

Key points that were raised included: Resilience as an organizing framework.

- The resilience framework provides an opportunity to rally support for conservation, as it can be understood and communicated at many levels. This is particularly important where stakeholders must be involved at all steps of the process.
- Adaptive management and climate change both provide a challenge for involving stakeholders, as issues and priorities can change regularly. The resilience framework helps in this, as different issues can be incorporated into the same overall framework such that the overall goal doesn't change while some of the issues may.
- Management priorities differ among places. For example, climate change has not had a major impact yet in Bonaire or Indonesia, so reef managers don't pay much attention to it. The resilience approach can help in ensuring currently low-priority threats are nevertheless kept in mind as potential problems in the future, and for comparing the success of management interventions under different threats.

Economic value of coral reefs needs to be emphasized, but not just in dollar terms, as this may just put reefs on the market. Other social and services values also need to be expressed (e.g. job creation) that cannot just be bought and sold on the market, and the recurrent value of living resources emphasized (fish for viewing by tourists every day, as opposed to for eating only once). With respect to resilience, the value of strong drivers of resilience could be determined – e.g. the value of herbivorous fish in maintaining the system, not just for tourist viewing or eating.

Communication, awareness and education are vital foundations for stakeholder involvement, from tourists to local communities to businesses. The role of resilience needs to be clearly communicated, and may be relatively easy, for example in the importance of fish herbivores.

Emphasis will be on identifying the most effective methods for expanding the application of resilience in coral reef systems. This workshop will strengthen the consensus on understanding climate impacts on coral reefs as it follows a workshop focused on resilience science and feeds into a workshop focused on policies that support resilience-base management. Our goal is to make sure that the new tools and approaches get into the hands of coral reef managers attending the Congress and provide them with some definitive ideas of how to apply the tools to their own work and management problems.

Building resilience-based policy

The third session in the resilience workshops had as its goal to outline and discuss policy approaches that have succeeded in addressing climate change as a problem in marine ecosystems, and to discuss how these might be targeted towards the specific problem of coral reefs and climate change, as well as thinking more broadly to other ecosystems in and beyond the marine realm. With little solid work to date on policy responses specifically on resilience, more time was devoted to the presentations. This synthesis focuses on common themes among the presentations, key opportunities to link science, management and policy, and enabling policy responses within the scope of the IUCN as an organization and the World Conservation Congress.

Resilience, adaptive management and adaptation to climate change

Resilience-based thinking promotes a more holistic view of management and required actions, and the policy needed to support these. Examples of this more holistic perspective are the following:

Support resilience actions by managers.
The science session outlined how key actions can be identified to maximize resilience, and the management session outlined the opportunities and constraints that managers face in managing for resilience. A key need is to raise awareness in policy circles that scientific knowledge and management responses are known and can be implemented, and that new knowledge often results in new recommendations for action. Thus policy changes are often needed to support implementation, and to be adaptable. To enable this, the higher decision-making levels in institutions and countries need to recognize the need to devote resources to build capability to respond to climate threats, to adapt as new issues become critical, and to finance the necessary actions.

Adaptive management
Is essential for responding to climate change. With constantly changing background conditions (slow drivers, such as increasing CO_2 concentrations and temperatures), wider fluctuations in extreme conditions (storms, super-warm years, etc.), greater disparities between rich and poor and unpredictable social and political responses to all these conditions, management frameworks must have built-in capability to adapt to changing contexts.

Increasingly holistic and multisectoral approaches.
This goes across the board from understanding linkages among adjacent ecosystems, such as coral reefs, mangroves and seagrasses, to linkages between land and sea, such as in watersheds and Integrated Coastal Management approaches. Similarly, linkages from environmental and ecological sciences to social and political dimensions, and engineering and technical professions need to be built up, to ensure actions are consistent and mutually supportive.

Social resilience and adaptation.
To maximize social resilience and the ability of people to choose options that are for the common good and sustain goods and services, a supportive policy environment is essential. Characteristics of

such an environment are recognition of group responsibilities and rights, internalization of third-party and common property costs, and operationalization of precautionary or stewardship approaches to environmental and resource management. For any particular society, this needs to be done in ways that maximize acceptance and compliance, i.e. that are based on locally appropriate social, cultural and psychological values and frames of reference.

Expert consensus statements.

These vary from relatively informal gatherings with published outputs, to the top levels of global scientific opinion. The value of these statements is that they condense a consensus view of the problem, with increasing rigour as the forum increases in its representation of major countries and technical institutions. These statements have considerable power in justifying action at management and policy levels. Examples of recent consensus statements include:

- Technical – Townsville Declaration (2002) on coral bleaching, convened by the Center for Coral Reef Biodiversity of James Cook University, Australia; the Honolulu Declaration (2008) on ocean acidification, convened by The Nature Conservancy; statements on coral diseases (1999) and bleaching (2004) compiled by the International Society for Reef Studies.

- The International Coral Reef Initiative (ICRI) is a voluntary grouping of countries with membership of organizations, committed to coral reef conservation (www.icriforum.org). It provides an intergovernmental framework for commitment and actions to reduce threats to coral reefs, including the hosting semi-annual General Meetings and the 4-yearly International Tropical Marine Ecosystems Management Symposia (ITMEMS). Collectively, these provide a forum for delivering management action and simultaneously promoting supportive policies within and among the participating countries in ICRI, and closely linked with expert statements and technical support from the ISRS.

- Formal – Intergovernmental Panel on Climate Change (IPCC), which has released Assessment Reports on climate change most recently in 2001 and 2007, and feeds directly into the UNFCCC Convention process for formal commitments made by national governments.

Socio-economic valuation and costs of adaptation

At policy levels, climate change impacts and adaptation must be expressed in the same terms as other macro-economic and political issues, as illustrated by the impact of the Stern Review (2006). This includes financial costing, but also such things as resource dependency, employment levels and patterns and human costs such as in health, nutrition and similar indicators. As discussed in the science and management sessions, just putting a monetary value on ecosystems may only result in putting them on the market for the highest bidder, which may not effectively protect them. An alternative to this approach is to value the importance of functional processes and diversity to resilience within an ecosystem, i.e. to value an ecosystem in terms of ecological resilience rather than in monetary value.

A further challenge is that the costs of mitigation and adaptation for climate change, i.e. actions now to improve conditions in the future, appear exorbitant when compared with current costs that don't internalize environmental impacts, making it politically difficult to fully incorporate them. More effective internalization of future costs (with and without action now) is essential to crossing this policy barrier, and relate to how future costs are discounted under current practices.

The above challenges of valuation may potentially be amenable to some resolution through a resilience approach, as the identification of strong drivers, particularly relating to social acceptance of interventions, may provide new ways to approach valuation and target investments to minimize impacts.

Communicating the message

Effective communication of complex issues is a primary challenge for promoting policy development. While scientists couch statements in multiple disclaimers, a way to communicate the core message in terms meaningful to wider stakeholders and policy developers is essential. In this context, the adage 'less is more', and was highlighted by two examples:

- The Annual Report Card (ARC) on Climate Change developed by the MCCIP in the UK effectively dissected complex information on real and potential climate impacts, and the uncertainty associated with measuring and predicting them, into a succinct document meaningful to government institutions and decision-makers. A similar approach can be taken at many levels relevant to coral reefs, from local to national to regional, provided it is done within the relevant governance structures for moving forward from its message.

- The Phoenix Island Protected Area project, capitalizing on the pride of Kiribati people on their islands, ocean and maritime culture, condensed scientific message on the value of the Phoenix Islands into a video for public distribution, and that government officials carried with them to international meetings and fora. Together with intensive and personal communication and relationship-building with national decision-makers, the government has taken forward steps that have resulted in the largest MPA in the world combined with an innovative endowment scheme based on protected fishing values.

International conventions and institutions

By ratifying and signing conventions, countries commit to standards and actions specified under the conventions. Conventions are a principle instrument of agreement among countries, of which two of the most pertinent for climate change and biodiversity are:

- United National Framework Convention on Climate Change (UNFCCC) – The goal of the UNFCCC is to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. It sets out to reach this in a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. The convention text was adopted in 1992 but the last country signatures required to bring it to full force was obtained in 2006. A key instrument of the UNFCCC is the Kyoto Protocol, by which countries lay out mechanisms to reduce, and set limits on, greenhouse gas emissions to achieve the objectives of the Convention.

- Convention on Biological Diversity (CBD) – the goal of the CBD is conserve biodiversity, promote its sustainable use and achieve fair and equitable sharing of benefits derived from it. The convention sets out comprehensive commitments to protect and monitor biodiversity, and was the first convention to specify the importance of genetic resource to manking and at the country level. The convention was concluded at the Earth Summit in Rio de Janeiro in 1992.

At a different level, countries may signify their commitment to goals embodied in an organization. For example, the International Union for the Conservation of Nature (IUCN), with its membership of countries and organizations, provides a framework with multiple opportunities for policy support that bring the interests of varied stakeholders together, from countries to community-based organizations. The key policy instrument of the IUCN is the members resolutions tabled at the four-yearly Members Assemblies. Adopted resolutions directly influence IUCN and its members activities (through its Work Programme, Commissions and Membership), and indirectly influence external partners and collaborators. As a result of this workshop series, Resolution 4.080 was crafted during these sessions, and adopted at the Members Assembly (see p. 6). Implementation of policies can be through members activities, or more directly through IUCN Commissions and its quadrennial Work Programme. An example of the linkages between policy and implementation activities is the Global Marine Species Assessment (GMSA). It is expanding coverage of the IUCN Species Survival Commission's Red List of Endangered Species to marine species, which provides the technical foundation for policy instruments (e.g. the Convention on International Trade of Endangered Species, CITES), to be used for marine and coral reef conservation (see p. 29).

Priorities for policy development

Taking on board the observation that 'less is more' in addressing policy, it is clear that the message from coral reefs with respect to climate change is particularly stark, and one that should be used more effectively to drive policy change that may also cover a much broader range of ecosystems. With this in mind, the following policy recommendations emerge from the resilience sessions:

1) ***Coral reefs can influence public and policy opinion*** on the need to act on climate change in a holistic way. Resilience concepts may provide a sufficiently holistic framework to do this, providing explanations in understandable simple terms but also a rigorous framework for measurement, action and assessment.

2) ***Policy action on coral reefs and climate change needs to be planned within specific geographic or governance boundaries***, which may range from local government, to national government to intergovernmental levels. To support this, two parallel and supporting agendas need to be addressed, as exemplified by presentations from Australia and the UK:

    a. Provision and where necessary development of the relevant information on climate change impacts in an appropriate framework for the governance context. Where information is not sufficient this may require starting with assessments of climate change at the relevant scale, its impacts on physical and biological processes, vulnerability assessments at the social and economic levels, and from these development of a climate change action plan that draws on the relevant governance structures available.

    b. Building up of the governance framework for responding to climate change, which includes establishing broad-based stakeholder forums at two levels – of government departments and institutes with relevant though often separated capabilities and responsibilities (e.g. the MCCIP), and public stakeholders such as affected industries and social groups (e.g. the Great Barrier Reef).

3) At the global governance level, ***climate change impacts and adaptation fall under the United Nations Framework Convention on Climate Change (UNFCCC)***. Thus the message about climate impacts on coral reefs and opportunities for management and adaptation need to be fed into the UNFCCC process. From this level, the multitude of responses at regional and national levels can be supported. Points of entry to achieve this are:

    a. To improve the provision and consideration of coral reef and marine information within the Intergovernmental Panel on Climate Change (IPCC), which provides the core scientific consensus that informs the UNFCCC.

    b. To engage more effectively with the UNFCCC Conference of Parties (COP), and the setting of agendas and topics for consideration during the COPs.

    c. To identify key policy advisors in key countries (e.g. that are active within the International Coral Reef Initiative) to raise the profile of coral reefs within the IPCC and UNFCCC, capitalizing on their iconic status.

4) IUCN plays a unique global role as a convenor for conservation and sustainable development debates. Its strengths lie in its membership structure that includes most governments of the world, a broad range of private organizations and observer status at the United Nations. This provides a powerful policy role for the organization in reaching to all levels at which policy change has been advocated, and for supporting more effective management and adaptation to climate change. This discussion is hosted within the four-yearly IUCN World Conservation Congress, which provides an opportunity to call on IUCN members, programmes and commissions to support greater action on mitigating and adapting to climate change, and for similar action beyond IUCN's immediate reach. For consistency with the topic of these sessions, this resolution should specifically relate to coral reefs, the resilience framework discussed here, and climate change, but can also have relevance to other marine and even terrestrial systems. A resolution was drafted and adopted, reproduced in the next section.

Workshop abstracts

Coral reef resilience – coping with change through diversity

Streams - A new climate for change; Oceans and climate change
October 8 2008, 14:30-16:00

Tundi Agardy	Director, Marine Ecosystems and Management (MEAM)	Facilitator
Enric Sala	Fellow, National Geographic Society	Understanding reef community structure and health through resilience
Paul Marshall	Director, Climate Change, Great Barrier Reef Marine Park Authority	Why monitor resilience and what are the challenges in developing a protocol? What motivated developing a monitoring/assessment tool?
David Obura	Director, CORDIO East Africa/Chair IUCN Climate Change and Coral Reefs working group	Coral size class and recruitment, diversity – indicators of resilience in a coral population
Bob Steneck	Professor of Oceanography, School of Marine Sciences, University of Maine	Algae as Drivers and Indicators of Coral Reef Resilience
Alison Green	Senior Marine Scientist, Tropical Marine Conservation Program, Asia Pacific Conservation Region, The Nature Conservancy	Measures of resilience in fish populations; herbivore functional groups
Nadine Marshall	Sustainable Ecosystems, CSIRO	Building social resilience into marine conservation

Presentations showcased the work of coral reef scientists applying resilience principles in designing assessment and monitoring protocols for coral reef health and status, in an effort to work with managers to understand and limit damaging effects of climate change. The methods highlighted here build on a process initiated at the 2003 World Parks Congress and 2004 World Conservation Congress. The methods development process is supported by the MacArthur Foundation.

Coral reef ecosystem resilience depends on complexity. Enric Sala

We have defined resilience as the ability of an ecosystem to recover to its original state after a disturbance. But to measure resilience properly, first we need to define what is the original state, and also understand where the ecosystem was along the gradient of health before the disturbance. Because of the pervasive issue of the shifting baselines, and the fact that most coral reef science is conducted on reefs in the degraded section of the gradient of health, these are not trivial issues.

We argue that resilience needs to be seen in the light of ecological succession. There are predictable changes that occur along a successional sequence, regardless of the ecosystem and location. As an ecosystem recovers, the general trend is an increase in total biomass, productivity, species richness, structural diversity, three-dimensional structure created by living organisms (e.g., the coral reef matrix), complexity in general; and a decrease in the turnover rate (production/biomass ratio) (Odum 1976) (fig. 3). If we know the trends over time of the above variables – or proxies for these variables – we will know whether the system is recovering to a more mature/complex state and we will be able to measure resilience.

The more complex (or mature or intact) the ecoystem, the more resilient it is. A study of a gradient of human disturbance in the Line Islands in the central Pacific showed that corals exhibit greater recruitment and thus recovery from bleaching events the more complex the food web is (Sandin et al. 2008). That is, the more levels on the food chain there are, including the top predators, the more resilient the ecosystem is. This is what we would expect from all the work on terrestrial ecosystems, which shows that the presence of top predators can buffer the short term effects of global warming (Sala 2006).

The implications for management are clear: if we can restore complexity in the short term, we will foster the resilience of the ecosystem. On coral reefs, the first essential step to restore complexity is to reduce fishing pressure to allow the recovery of the fish community. To achieve this, the best available tool is no-take marine reserves, which have proved universally successful in recovering the complexity of the fish assemblages (PISCO 2008). Reserves are not the only solution, but they are an essential complement to the reduction of other local impacts (pollution, sedimentation), and global impacts (global warming) that will take a longer time to address.

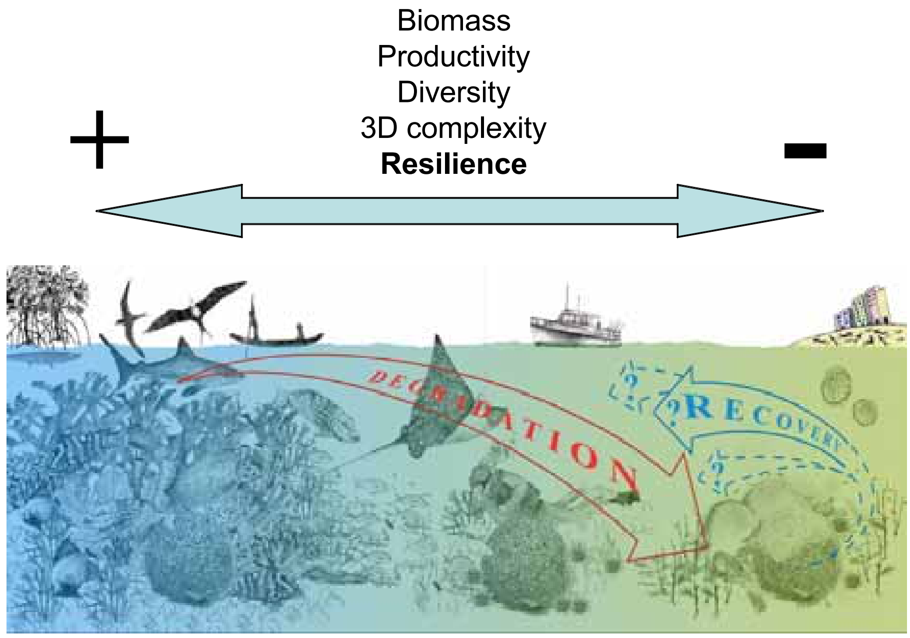

Fig. 3. Gradient of health/degradation of coral reefs, from pristine (left) to degraded (right). Most coral reef science has been conducte on reefs to the right of the canoe. Adapted from Pandolfi et al. (2005).

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Why monitor resilience and what are the challenges in developing a protocol? Paul Marshall

The challenge

Coral reefs are under unprecedented challenge. Against a backdrop of local anthropogenic stresses, including pollution, overfishing and habitat destruction has emerged the global threat of climate change. Already we are seeing the impacts, with over 16% of the world's reef's seriously damaged by coral bleaching events. Further change is inevitable, even if greenhouse gas emissions are stabilised. For managers, this means that coral reefs will increasingly be in a state of recovery, as disturbance events (such as mass bleaching) grow in frequency and severity. Therefore, managing for ecological stability is no longer an option: even the best managed reefs will decline as climate change progresses. The challenge for managers, then, is to reconfigure management objectives to focus on protecting the properties that enable reefs to cope with change. In other words, coral reef managers need to manage reefs for resilience.

One of the major challenges for progressing resilience-based management lies in the application of resilience principles. While general resilience principles are influencing the way practitioners approach coral reef management and conservation, there remains an urgent need for protocols for assessing and mapping resilience in coral reef ecosystems.

An operational framework for assessing resilience

The first step in practical application of resilience principles is to define resilience in operational terms: resilience of what to what? This workshop deals with coral reef vulnerability to climate change, in particular to rising sea surface temperatures. Hence we are looking at the resilience of coral communities to increasing sea temperatures. The specific attributes of coral communities that underpin key values include the abundance (cover) of corals, their contribution to reef accretion and the amount of habitat they provide. Two general properties determine the ability of coral communities to persist in the face of rising temperatures: their sensitivity and their recovery potential. Sensitivity is a combination of resistance (ability to experience exposure without bleaching) and tolerance (ability to survive once bleached); recovery potential is the likelihood that a coral will be replaced in the community once killed. Together, sensitivity and recovery potential determine the resilience of coral communities to rising sea temperatures (fig. 4).

For conservation practitioners and managers concerned with climate change, the capacity of coral reefs to sustain key ecosystem goods and services in the face of increasing sea temperatures is rapidly emerging as a focal issue. The array of benefits coral reefs provide human communities is vast, spanning recreational, tourism, fishing, shoreline protection, spiritual and biodiversity values. Ultimately, however, these values depend largely or entirely on the maintenance of healthy coral communities. One of the fundamental (although often implicit) goals for coral reef management and conservation, then, is to sustain the provision of ecosystem goods and services through the maintenance of healthy coral communities.

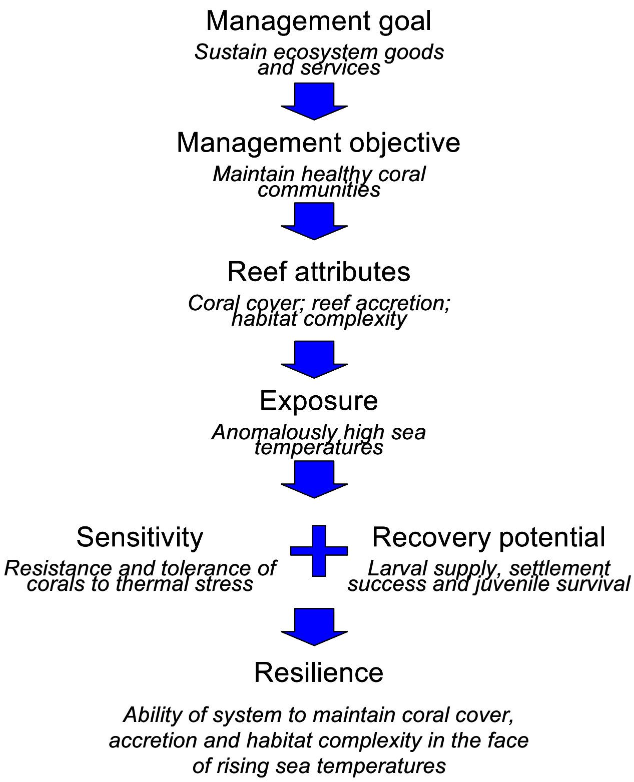

Fig. 4. Conceptual diagram for operationalising resilience in coral reef management. Italicised text provides specific examples for each general concept

The purpose for measuring reef resilience is to deconstruct the various reef attributes and driving processes in order to focus our understanding of reef health, and manager's attention on attributes and processes they can actively manage, and thereby improve the prospects for reefs surviving climate change impacts. Despite the urgent need and obvious appeal of resilience-based management, there remains much work to do in developing, testing and refining guidance for practical application of resilience principles. Initial work in the Great Barrier Reef has yielded encouraging results by demonstrating that resilience, at least when assessed at a local scale using generic indicators, is a feasible framework for coral reef planning and management. Testing of more detailed indicators by members of the IUCN Climate Change and Coral Reefs Working Group is also showing promising progress.

The IUCN-CCCR Coral Reef Resilience Assessment method. David Obura & Gabriel Grimsditch

Coral reefs and their associated seagrass beds and mangrove habitats support the highest marine biodiversity in the world. More than 500 million people worldwide depend on them for food, storm protection, jobs, and recreation. Their resources and services are worth an estimated 375 billion dollars each year, yet they cover less than one percent of the Earth's surface. Unfortunately, many of the world's coral reefs have been degraded, mainly due to human activities. According to the Status of Coral Reefs of the World: 2004, 70% of the worlds' coral reefs are threatened or destroyed, 20% of those are damaged beyond repair, and within the Caribbean alone, many coral reefs have lost 80% of coral species.

Climate change is now recognized as one of the greatest threats to coral reefs worldwide. While a changing climate brings many challenges to coral reefs, one of the most serious and immediate threats is from mass coral bleaching associated with unusually high sea temperatures. Coral bleaching has lead to substantial damage to coral reefs on a global scale (16% of reefs suffered lasting damage in 1998 alone), with some areas losing 50-90% of their coral cover. Further degradation is predicted: severe coral bleaching events may be an annual occurrence by mid-century, even under optimistic climate scenarios.

Additionally, coral reefs are under pressure from a variety of human activities, including catchment uses that result in degraded water quality, unsustainable and destructive fishing, and coastal development. These local pressures act to reduce the resilience of the system, undermining its ability to cope with climate change, and lowering the threshold for the shift from coral-dominated phase to other phases. Increasingly, policy-makers, conservationists, scientists and the broader community are calling for management actions to restore and maintain the resilience of the coral reefs to climate change, and thus avoid worst-case scenarios.

The resilience assessment protocol is designed to provide a rapid assessment of coral bleaching resistance and resilience at an individual site level. This is intended to facilitate assessment of any past management actions in maintaining the resilience of coral reefs, and the making of new management decisions against local MPA objectives.

While the assessment protocol can be undertaken as an independent study, it is most useful in an adaptive management structure that already incorporates annual or routine monitoring. Thus routine monitoring provides background time series information on a limited set of variables that track coral reef status and function over time. The resilience assessment is designed to be undertaken to increase understanding of the resistance and resilience of reefs to bleaching, whether a bleaching event has occurred in the past or not, and in relation to other threats. This assessment need be done only once, then perhaps repeated after a long period (e.g. 5 years) or after a major event (e.g. bleaching, or other major pulse stress such as a cyclone, COTs outbreak, etc.).

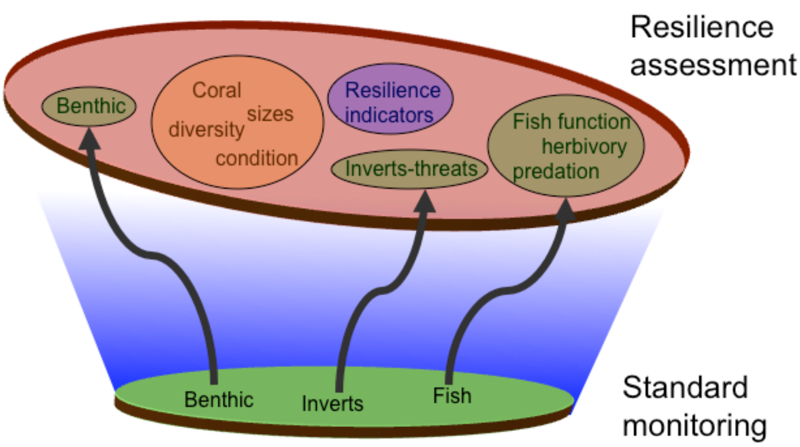

Fig. 5. The resilience assessment builds on the foundation of standard monitoring procedures, adding further detail on coral community and site-based resistance/resilience to bleaching. Principal additions relate to coral community characteristics, fish functional groups and resilience indicators, based on the models outlined in figures 1 & 2.

The main components of the resilience assessment measure the following components:
1) Benthic cover and algal community structure;
2) Coral community structure (genera);
3) Coral size class distribution, including recruitment. Focus on selected genera with low, medium and high bleaching susceptibilities;
4) Coral bleaching, disease, other condition and threats;
5) Fish community structure, with a focus on fish herbivore functional groups; and
6) Resilience indicators. These cover a broad swathe of physical, biological and anthropogenic factors that affect coral and reef health, including some of the components measured quantitatively in parts 1-5. The major classes of resistance and resilience indicators include:
   a. Substrate and reef morphology
   b. Algal community
   c. Cooling and flushing
   d. Shading and screening
   e. Extreme conditions and acclimatization
   f. Coral condition
   g. Coral population structure
   h. Coral associates
   i. Fish functional groups - herbivory
   j. Connectivity
   k. Anthropogenic factors.

The presentations and papers focus on aspects of the assessment protocol (justification, coral size classes, algae and herbivorous fish) to focus on how science can be used in support of management and policy, and to identify next steps for using and improving the assessment method and conserving coral reef resilience.

The manual for this method can be downloaded from http://cms.iucn.org/cccr/publications/

Indicators of resilience in a coral community. David Obura

Resilience as a framework for managing coral reefs is gaining ground amongst practitioners, so we are now faced with the problem of measuring and understanding resilience in specific terms. This presentation deals with the question of what a 'resilient coral community' looks like, as this must be the dependent variable against which factors affecting resilience must be assessed. The IUCN CCCR Resilience Assessment protocol has a number of modules focusing on coral population and community structure, and these are described here.

Corals experience stress during high temperature events, and can bleach and die as a result. Two characteristics define the ability of a coral community to maintain its functions and state under such conditions:

Resistance – being the ability of individual cora-zooxanthellae holobionts to resist bleaching under thermal stress, and/or if they bleach, to tolerate (resist) it and not suffer mortality. This is thus a phenotypic property of the coral individual (but a population property of the zooxanthella symbionts), with genotypic and environmental components that enable acclimatization (successful resistance) and adaptation (selection following mortality).

Resilience – being the population or community level property of recovery through regrowth of surviving coral colonies and/or recolonization and growth by propagules from surviving colonies.

Quantifying resilience of a coral community thus requires considerations of both of these factors.

Cover

Traditional measures of coral cover from a monitoring programme may be insufficient to distinguish coral populations with different resistance/resilience properties, as two populations can have the same total cover, but one be made up of old surviving colonies, the other just of new rapidly growing colonies.

Diversity
The interpretation of coral cover data is improved by taxonomic knowledge, such that populations dominated by corals with different bleaching susceptibilities and reproduction/regrowth characteristics can be more clearly distinguished from each other. However sampling using transects or quadrats undersamples rare species and genera, and overall diversity, so time-based sampling of coral genera (or species) on a basic abundance scale (e.g. 5-points) provides a rapid way to determine the population/community level contribution of coral genera with different bleaching and growth strategies. Various measures can be used, including the use of k-dominance curves and ranking by bleaching strategies of corals.

Population structure
The size class structure of corals gives a detailed approximation of the age-class structure of coral communities and/or of the disturbance regime affecting a community. Because of the indeterminate growth of many dominant coral species, size class distributions based on both the number and area of individual colonies give detailed information on recruitment, post-settlement survival and transitions between large size classes, the effect of disturbances reducing the number of large and medium-sized corals, and the legacy of past disturbances on the modal structure of curves. By selecting coral genera representative of different bleaching susceptibilities (low, medium and high), further inferences can be made about past impacts and resistance to future stress.

Interpretation
With the above information in hand, the current state and history of the coral community can be described, against which data on other ecological components (e.g. algal population, herbivores), or physical resistance/resilience indicators (e.g. upwelling of cool water, screening by turbidity plumes), can be compared.

Reports and analysis guides for this method can be downloaded from http://cms.iucn.org/cccr/

Algae as Drivers and Indicators of Coral Reef Resilience. Robert S. Steneck

Algae and corals are two of the main benthic groups that dominate coral reefs. They compete for space, with the outcome dependent on many factors. A phase shift can occur to an algal-dominated by a shift in the controlling conditions. In studying reef resilience we are interested in the ability of a reef to resist such a phase shift to an alternate (often algal-dominated) state and/or to recover to its original state following a disturbance.

Algae come in several functional groups, with different effects on corals. The groups include turfs (individual hair-like fronds too small to distinguish their identify, forming a thin 'lawn' less than a millimeter to several millimeters thick), corallines (calcified encrusting or immovable branching forms), calcareous macroalgae (calcified green algae, such as *Halimeda*) and fleshy macroalgae (distinct fleshy algal fronds). Thick turfs and macroalgae can be deleterious to corals. Negative effects of high algal biomass include smothering of corals, reducing their feeding and reproductive output; promotion of coral disease; and reductions in coral recruitment and post-settlement survival. Some coralline algae, in contrast, facilitate the recruitment and survival of juvenile corals.

We define healthy coral reef resilience as the ability of a reef to resist a phase shift to an alternate (often algal-dominated) state and/or to recover to its original state following a disturbance. Thus, algae are both drivers and indicators of the resilience of coral reef ecosystems, and a high priority for inclusion in resilience assessments of coral reefs. Algae are easy to quantify and trends can be highly diagnostic of management concerns or successes.

Monitoring Functional Groups of Herbivorous Reef Fishes as Indicators of Coral Reef Resilience. Alison Green

Coral reefs are the most structurally complex and taxonomically diverse marine ecosystems on earth, providing ecosystem goods and services for millions of people worldwide. Coral reefs are seriously threatened by a variety of anthropogenic threats, particularly unsustainable fishing practices and runoff from poor land use practices. Up to 70% of the world's reefs are under direct threat from these activities, and serious and widespread declines in coral reef health have been reported around the world.

Climate change represents a new and increasing threat to coral reefs worldwide. Major threats include rising sea temperatures, rising sea levels and changes in ocean chemistry. Urgent action is now required to halt or reverse these threats and declines in coral reef health. One approach is to manage for coral reef resilience.

Coral Reef Resilience
Resilience is the ability of an ecosystem to absorb shocks, resist phase shifts and regenerate after natural and human-induced disturbances. For coral reefs, it is the ability of reefs to absorb recurrent disturbances, and rebuild coral dominated systems rather than shifting to macroalgal dominated systems. Coral reef resilience will be increasingly important in future as disturbances become more frequent and severe with climate change.

Several key factors are critical for ensuring coral reef resilience. They are predominantly factors that influence coral recruitment, particularly larval supply, water quality, substratum consolidation, conditioning by biological agents, and the presence of sessile invertebrates or dense stands of macroalgae that impede coral recruitment, growth and survival.

Role of Functional Groups of Herbivorous Reef Fishes
Herbivores play a critical role in coral reef resilience by limiting the establishment and growth of macroalgae communities. On coral reefs in the Indo-Pacific Region, fishes are the dominant group of herbivores, while both echinoids and fishes are important in the Caribbean. Major families include surgeonfishes, parrotfishes, rabbitfishes and rudderfishes.

Herbivorous reef fishes are diverse and do not constitute an ecologically uniform group. They comprise several functional groups, which differ in terms of how they feed, what they consume, and their impact on the underlying substratum. Four functional groups of herbivorous reef fishes are distinguished that each play different roles in coral reef resilience:

<u>Scrapers and small excavators</u> are two groups of parrotfishes that show major differences in their jaw morphology and feeding behaviour. Both feed on epilithic algal turf, and remove some component of the reef substratum as they feed. They differ in the amount of the substratum they remove while feeding, and their contribution to ecosystem processes such as bioerosion. The majority of parrotfishes (*Hipposcarus* and *Scarus* species) are scrapers. They take non-excavating bites and remove algae, sediment and other material by closely cropping or scraping the reef surface, leaving shallow scrape marks on the reef substratum. Excavating species (*Bolbometapon muricatum, Cetoscarus bicolor* and all *Chlorurus* species) differ from scrapers by taking deeper excavating bites and removing greater quantities of substrata with each bite. Scrapers and small excavators play similar roles in coral reef resilience by limiting the establishment and growth of macroalgae while intensely grazing epilithic algal turf, and providing areas of clean substratum for coral recruitment. They also play an important role in bioerosion on reefs.

<u>Large excavators</u> play a similar role in coral reef resilience to scrapers and small excavators. They are also major agents of bioerosion on reefs, removing dead coral and exposing hard, reef matrix for coral recruitment. They include all large individuals of excavating species (see above). Five species have also been observed grazing on live corals on Indo Pacific reefs, although this only accounts for a substantial proportion of the diet of one species (*B. muricatum*).

<u>Grazers and grazers/detritivores</u> play an important role in coral reef resilience by intensely grazing epilithic algal turfs, which can limit the establishment and growth of macroalgae. Unlike parrotfishes, they do not scrape or excavate the reef substratum as they feed. Grazers include small rabbitfishes, small angelfishes (all *Centropyge* species), and many species of surgeonfishes (all *Zebrasoma* and *Acanthurus* species except those that feed exclusively on plankton or are grazers/detritivores). Grazers/detritivores include *Acanthurus* species that feed on a combination of epilithic algal turf, sediment and some animal material. Although only a small proportion of their diet is algae, grazers/detritivores are included because many are schooling species that can be abundant and consume significant amounts of algal turf.

<u>Browsers</u> consistently feed on macroalgae. They select individual algal fronds and remove only algae and associated epiphytic material. Browsers play an important role in reducing coral overgrowth and

shading by macroalgae, and can play a critical role in reversing coral-algal phase shifts. They include some unicornfishes, batfishes, large rabbitfishes and parrotfishes of the genus *Calotomus* and *Leptoscarus.*

Monitoring Functional Groups of Herbivorous Reef Fishes
Coral reef monitoring has traditionally focused on monitoring the status of coral communities and populations of conspicuous species, particularly targeted fish and invertebrate species. While these measures provide useful information of the current status of coral reef communities and fisheries species, they do not provide information on the status of key ecological processes that are essential for maintaining coral reef resilience.

Developing new metrics for monitoring coral reef resilience that are process oriented is an urgent priority for improved management of coral reefs. Monitoring coral reef resilience will require a combined approach to monitoring key ecological processes, and functional groups that contribute to these processes including:

- Coral population dynamics (size structure and patterns of recruitment).
- Factors that influence coral recruitment and survivorship, particularly water quality, substratum consolidation, and benthic communities (particularly macroalgae).
- Factors that influence the establishment and growth of macroalgal communities, particularly functional groups of herbivores.

Methods for assessing and monitoring coral reef resilience are currently being developed by the IUCN Working group on Climate Change and Coral Reefs. The following is a protocol for monitoring functional groups of herbivorous reef fishes developed as part of this process. Standard monitoring protocols are used to facilitate their integration into programs where field practitioners are interested in monitoring for multiple objectives (e.g. status of key fisheries species and coral reef resilience). They are not intended to represent the only method that should be used to monitor coral reef fishes, and in most locations, are expected to form part of broader monitoring programs based on multiple objectives.

Key components include:

- A hierarchical or stratified sampling design.
- Site selection of representative areas with adequate space to conduct the program.
- Standardising coral reef exposures and zones (reef crests and slopes on exposed linear reef fronts).
- Survey timing (between 9am and 4pm) and frequency: Long term monitoring requires a baseline survey, repeated every three years or more frequently if required to monitor success of management actions or impacts of large scale disturbances. Rapid assessments usually comprise a single survey on one occasion.
- Underwater visual census methods for rapid assessments (30 minute timed swims) and long term monitoring (combination of five 50m belt transects and 20 minute long swims) to assess both density and biomass of herbivore populations.
- Minimising disturbance to fish communities.

These methods are under development, and further field testing and refinements are still required. A major challenge is interpreting the results in the broader context of coral reef resilience.

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Building social resilience into marine conservation. Nadine A. Marshall

Resilience is emerging as an important concept to guide and support more inclusive and effective approaches to the management of combined systems. Knowledge of the properties that confer resilience can assist resource-managers, communities and resource users to design and implement policies that minimize the impacts on people while maximizing the sustainability of ecosystem goods and services. Resource managers can design resource-protection strategies that are least inclined to erode the resilience of the social-ecological system and maximise the system’s ability to cope with future disruptions. Such strategies are more likely to be socially acceptable, inspire less conflict and gain higher compliance.

Despite the appeal of resilience as a framework for sustaining human-environment relations, resilience is complex, context-specific and highly dynamic, which has slowed the development of general tools and methods of application. Even in theory, the locations of thresholds between desirable and undesirable states are difficult to measure, and are subject to shift over time due to the complex and dynamic behaviour of resource systems. Conceptual frameworks and operational tools are beginning to emerge that enable social resilience to be built into marine conservation. In this paper we present initial operational definitions for resilience that have been developed and applied in both Australia and Egypt in various contexts.

Quantifying social resilience

Social resilience is a complex and multidimensional concept that describes the capacity of resource-users, industries and communities to cope and adapt to stressful change events such as Marine Protected Areas. Conceptual frameworks and operational tools define social resilience as comprising at least 4 essential components: (i) the perception and management of risk, (ii) the proximity to financial and emotional thresholds, (iii) the capacity to plan, learn and reorganise, and (iv) the level of flexibility.

Standard social science methods can be used to assess these indicators. The resultant assessment provides a relative measure of social resilience and enables the nature of vulnerability to be identified (and addressed) so that resources directed at enhancing social resilience can be best targeted for maximum effect. For example, some individuals/communities may be most vulnerable in their capacity to plan, learn and reorganise. Efforts to maintain social resilience will thus be best effective if targeted at developing human capital within the region through workshopping and training rather than through the provision of financial capital.

The dimensions of social resilience

1. The perception and management of risk. Risk-averse resource-users are less likely to experiment with their options for the future and are less likely to explore creative solutions to increase their chances of successfully adapting.

2. The ability to plan, learn and reorganise. Adaptation processes do not occur unless people use novelty, creativity, experimentation, learning and planning in approaching change. Individuals that can visualise the requirements of the future, can read important feedback information, can learn and act, are more likely to be able to cope and adapt.

3. The proximity to emotional and financial thresholds. Not all resource-users will perceive that they can cope sufficiently well with change. This dimension reflects other events occurring in people's lives such as tragedies, emotional or financial turmoil, including the level of confidence that people have in approaching change.

4. The level of flexibility as measured by the level of interest in change and the extent to which alternative livelihood options are perceived to be available. Without perceived options for the future people are severely restricted in their capacity to adapt.

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Managing for Coral Reef Resilience: Recent Developments and New Directions

Streams - Healthy environments – healthy people/Oceans and climate change
October 8 2008, 16:30-18:00

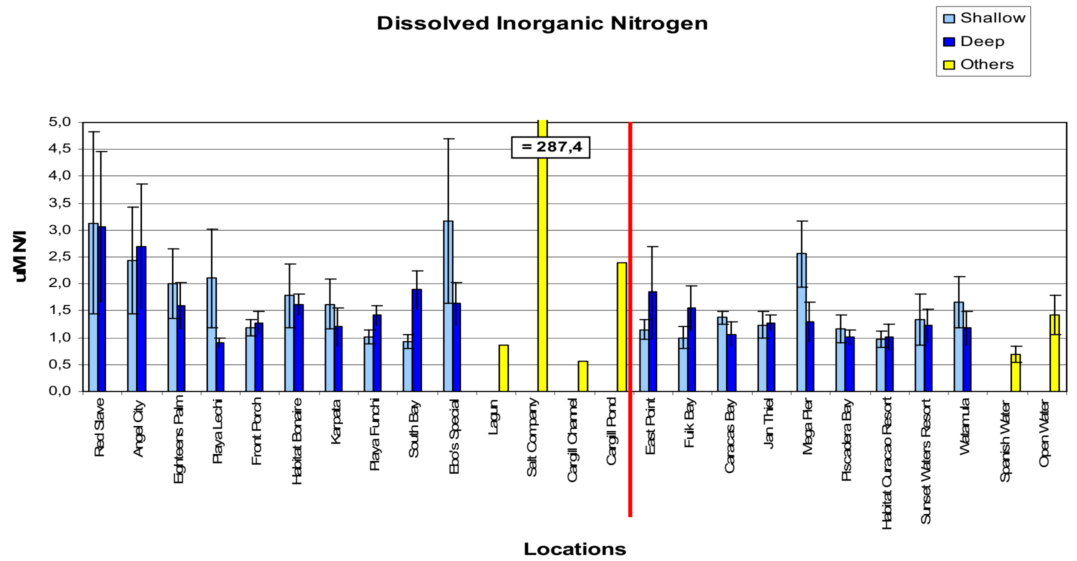
Paul Marshall	Director, Climate Change, Great Barrier Reef Marine Park Authority	Facilitator
Alison Green	Senior Marine Scientist, Asia Pacific Conservation Region, The Nature Conservancy	Resilience-based Marine Protected Area Design in Kimbe Bay, Papua New Guinea
Ramon de Leon	Warden, Bonaire Marine National Park (STINAPA)	Improving Wastewater Management to Increase Reef Resilience in Bonaire
Rodney Quatre	Head of Research, Seychelles Centre for Marine Rsearch and Technology – Marine Parks Authority (SCMRT-MPA)	Innovative approaches to enforcing remote marine protected areas
Stephanie Wear	MPA Scientist, Global Marine Team, The Nature Conservancy	Resilience-based management: training, implementation, and new tools

Resilience-based Marine Protected Area Design in Kimbe Bay, Papua New Guinea - Alison Green

Climate change represents a major threat to the long term future of coral reefs and associated ecosystems around the world. In recent years, principles for designing marine protected area (MPA) networks that are resilient to the threat of climate change have been developed. They include: spreading the risk through representation and replication each habitat type; protecting refugia (particularly those most likely to survive the threat of climate change); incorporating biological patterns of connectivity to ensure that MPAs act as mutually replenishing networks to facilitate recovery after disturbance; and effective management of other threats to reef resilience (particularly overfishing of functional groups of herbivores, and runoff from poor land use practices). In 2006, The Nature Conservancy and partners completed a scientific design of a resilient network of MPAs for Kimbe Bay in Papua New Guinea. This represents one of the world's first MPA networks specifically designed to address the threat of climate change, based on these resilience principles. Most principles were applied successfully, although some will require further refinements as new scientific methods are developed and more information becomes available. Major challenges included identifying and incorporating biological patterns of connectivity and areas that are most likely to survive the threat of climate change. Implementation of the MPA network is now underway through a detailed community based planning process. Since communities are the marine resource owners and decision makers in the bay, final decisions regarding the MPA network design will be at their discretion.

Improving Wastewater Management to Increase Reef Resilience in Bonaire - Ramon De Leon

Bonaire is situated in the southern Caribbean (12°10'N, 68°15'W) approximately 100 km north of Venezuela. The total area is 28,100 ha. It is home to 15,000 inhabitants and receives approx 60,000 tourists a year. STINAPA Bonaire is the NGO in charge of the management of the Bonaire National Marine Park (BNMP) and the Washington Slagbaai National Park (WSNP). The Bonaire National Marine Park was established in 1979. The Park starts at the high water mark and extends to 200 ft (60 meters) of depth; it covers an area of 6672 acres, or 27 km². From March 2006 until March 2008, a nutrient monitoring program was carried out in 8 sites in the west coast of Bonaire and 2 in Klein Bonaire. The nutrient monitoring project was an initiative of the NACRI (Netherlands Antilles Coral Reef Initiative), and organized by the department of Nature and Environment of the Netherlands Antilles (MINA), and STINAPA Bonaire, together with Reef Care Curacao, the Section Environmental Management in Bonaire (DROB-MNB), and the Agriculture and Fisheries Service (LVV) in Curacao.



The Problem
Preliminary analysis of the results show alarming levels of Dissolved Inorganic Nitrogen beyond the threshold value for coral reef systems (1 μ/liter) in almost all monitoring stations for both shallow (5 m) and deep (18 m) reefs. The source was identified as sewage seepage from non-functional septic tanks or bad irrigation practices in shore line properties

The Solution
Reduce all possible local stressors was the R2 Principle appropriate to work out this problem. The component of *Effective Management* was selected from the TNC Resilience Model in order to stop the threat and enhance coral recovery. Major lobbying was necessary to upgrade the proposed sewage treatment plant from secondary to tertiary treatment. To have a better idea of the amount of fresh water seeping into the sea, a "water balance" for 22 ocean front properties was completed. The objective of this exercise was to help ocean front properties improve their fresh water management.

Since the sewage treatment plant will be operative in 2012 an action plan was set between the BNMP and the Environmental Management Office of the Government in order to reduce seepage during the transition period. The action plan was approved by the Executive Council of the Island. The Government lobby together with the BNMP in order to obtain the financial resources to implement the plan.

Results
- The European Union committed an additional € 5 million to finance the extra tertiary treatment.
- After some initial reluctance, the tourism sector agreed to improve wastewater management developing better irrigation practices and avoiding leakage from septic tanks.
- The Netherlands authorized the local Government to transfer funds from other development funds to implement the Action Plan for the transition period (1 million €).

Lessons Learned
- Early involvement of a large number of key stakeholders and politicians makes the implementation of the plan less vulnerable to political changes and more reliable.

Gaps
- inappropriate standards for wastewater discharge prove to be one of the most important obstacles to address this problem.
- Local legislation not completely clear in the issue of discharge and therefore not easy to apply.
- The Cartagena Convention – Land Based Sources of Marine Pollution Protocol still not enforceable.

Needs
- Regional agreement on specific standards for sewage discharge in coral reef environments.

Resilience-based management: training, implementation, and new tools. Stephanie Wear

To promote reef resilience techniques, the The Nature Conservancy has developed a multi-modal approach focusing on science, tools, and resource manager knowledge and communication. We also actively engage Conservancy partners in our work to leverage existing knowledge and resources. Through the Reef Resilience Partnership, the Conservancy has worked with NOAA, IUCN, CORDIO, GBRMPA, WCS, WWF, and CI. This partnership draws upon many different skill sets, approaches, technical resources, and makes it possible to reach a diversity of field programs across the globe.

The Conservancy has developed an outreach program that employs different strategies to build capacity, including targeted training programs with tailored follow-up, a practitioners' network to facilitate communications, a training workshop series, and web-based resources. As part of this approach, we developed the R^2 (*Reef Resilience)* Toolkit, a multimedia CD-ROM toolkit that helps coral reef and MPA managers build resilience into their coral reef conservation programs so that valuable marine ecosystems can survive.

To strengthen communications between marine managers, the Conservancy and partners developed the R^2 Toolkit as well as a series of training workshops carried out around the globe. Our goal was to catalyze action and enable managers to take steps to decrease impacts of climate change on coral reefs and associated habitats. The first Reef Resilience Training Workshop was implemented in early 2005 in the Caribbean, and included 30 coral reef practitioners from 10 Caribbean countries. This workshop was followed by training workshops in the Western Pacific Islands, Southeast Asia, Western Indian Ocean, and South Asia. Through these partner-supported workshops, we trained more than 150 managers from 35 countries and territories. Using the curriculum developed by the Conservancy, partners such as International Union for the Conservation of Nature (IUCN) and NOAA conducted additional training workshops in the South Pacific, Red Sea, Australia, and Caribbean.

From the beginning, the Conservancy's goal has been to develop a network of coral reef practitioners dealing with the impacts of climate change and other threats and link them to scientists who are working to address their problems using innovative methods. In the early days, the network was comprised of R^2 Toolkit recipients, and it has grown to include Reef Resilience workshop participants and a broader community of coral reef practitioners by request. As the network has developed, the emphasis has shifted from information distribution to two-way communication by drawing lessons and experiences from the field that are then shared more broadly through formats such as the R^2 Toolkit.

Building resilience concepts into policy – sustaining environments and people through change

Streams - Healthy environments – healthy people/Oceans and climate change
October 8 2008, 18:30-20:00

Paul Marshall	Director, Climate Change, Great Barrier Reef Marine Park Authority (GBRMPA)	Facilitator and Converting socio-political momentum into conservation action in the Great Barrier Reef.
Jennie Hoffman	Senior Scientist, EcoAdapt	Motivating adaptation to climate change in marine systems.
Dan Laffoley	Chief Scientist's team, Natural England	Making climate science relevant to policy: The UK Climate report card.
Kent Carpenter	Director, Global Marine Species Assessment. Professor, Old Dominion University	Red Listing Coral Species: Strategies and opportunities to strengthen marine conservation policy and action in the Coral Triangle Region.
Greg Stone	Vice President, Global Marine Programmes, New England Aquarium, and Phoenix Islands Protected Area.	Wilderness area protection and sustainable financing in a Small Island Developing State – Kiribati
Lynne Hale	The Nature Conservancy	The Honolulu Declaration on ocean acidification and coral reef management.
Nadine Marshall	Sustainable Ecosystems, CSIRO	An approach to building the human dimension into marine conservation

The presentations highlight several policy approaches that have been successful in different contexts in approaching the problem of climate change for coral reef management. Discussion will focus on some of the challenges in developing and applying policy, and opportunities for policy action. The aim is to identify opportunities to improve the adoption of science and management recommendations for coping with climate change, and generalizing from coral reefs to other vulnerable ecosystems.

Resilient Policy, Resilient Reefs: How Do We Get There? Jennifer Hoffman

Science, management, and policy represent three levels at which action can be taken to support reef resilience. Science provides the data to inform management and policy. Management represents the application of the scientific information to achieve a desired set of results. Policy provides the context in which management decisions are made and carried out, the philosophical framework for linking science with action. Unlike science and management, policy must reflect both data AND societal values. A resilient policy will be able to absorb changes in science, and will reflect deeply-held societal values unlikely to change rapidly.

Because the field of resilience-based policy is relatively undeveloped, both practical examples and theory are a bit thin. I will therefore build this concept note around a series of questions, namely:
1. How can policy help or hinder coral reef resilience?
2. How might we motivate and implement resilience-based policy at different levels?
3. What is the right level at which to formulate policy that really makes a difference?

1. How can policy help or hinder coral reef resilience?
For communities of resource users, managers, or scientists who already want to increase resilience, policy should facilitate or at least not hinder their ability to take necessary action. This should generally include providing financial and governance mechanisms for ongoing funding, leadership, outreach, and capacity-building. Ideally, policies should be written with recognition of the appropriate spatial and temporal scales for maximizing actions to support the resilience of coral reef ecosystems.

In the case of a rapidly-evolving field like climate change conservation, policy needs to allow for the development and application of new management tools. A policy that mandates fixed five-year management plans, for instance, would make it more difficult for managers to put new information into practice during the five-eyar term. In contrast, a policy that provides explicit guidance for putting adaptive management into practice would be more likely to increase ecosystem resilience. For instance, the Environmental Impact Statement/Report for the South Bay Salt Pond Restoration Project in California, USA, identifies modeling, monitoring, and applied studies needed to address uncertainties and monitor project success, as well as institutional structures and processes necessary for successful implementation of adaptive management.

On a spatial scale, policies that focus only on the reef itself are much less likely to lead to resilient reefs than those that encompass as much of the area influencing the reef as is practical. For instance, land use in watersheds that feed into coral reefs can have a significant influence on reef resilience (e.g. sedimentation and fertilizer runoff resulting from clear-cutting, animal husbandry, or agriculture). To the extent that reef managers can be given or exert influence over land use decisions affecting their reefs, resilience will be increased.

One interesting avenue for exploration is how we might apply lessons learned about societal resilience to change to the resilience of policy and management systems to climate change. For instance, Nadine Marshall reported that individuals who feel that they have only a restricted number of options for action are less likely to be resilient. Might policies that lead managers or resource users to feel that their options for action are limited in fact lead to lower resilience, while those that allow or encourage creative responsive action produce greater resilience of both ecosystems and the human communities that interact with them? Granting greater responsibility and authority to local managers or stakeholders, provided they are also given adequate technical and financial support, may in some cases lead to more resilient ecosystems. This is presumably one reason why rights-based fisheries are more resilient (Costello et al, 2008). In any event, strong public engagement is critical to generate the necessary support and insight for adaptive management.

Policy itself needs to be adaptive. Likewise, there needs to be a flow of information from policy-makers to managers and scientists about what information they are using to set policy, and what further information would be helpful. And there needs to be information flow amongst government officials with overlapping jurisdiction to avoid working at cross-purposes. In Vietnam, for instance, economic development programs have sometimes ended up clear-cutting mangroves forests that had only recently been restored or replanted as part of resilience-building activities.

2. How does one motivate and implement resilience-based policy at different levels?
The most effective approach for creating resilience-based policy depends on the sociopolitical context in which it will be enacted, and on the reasons why resilience-based policies have not previously been enacted. Real community engagement in policy development is essential, both to provide community members with a greater sense of ownership and to allow the policy to reflect needs and concerns of those who will be affected. Even if a policymaker's goals are strictly focused on biodiversity conservation, extensive engagement with local communities to ensure that their issues are aired may be the most expedient path, as highlighted in several case histories from the United States (Bernstein et al, 2004). Assessing the concerns of stakeholders at all levels (government, civil society, resource users, etc.) and the resources (financial, social, or other) available for ensuring compliance is as important to generating resilience-based policy as the scientific information. If stakeholders do not perceive the necessity of building reef resilience, education would be the appropriate response. If, in contrast, they understand the arguments for reef resilience but feel helpless to do anything, practical advice and training would be good.

Generally, some significant portion of stakeholders will need external motivation, either positive or negative incentives. Such incentives may best be developed at the scale of the stakeholders involved, e.g. minimizing the social costs of conservation/maximizing the social costs of not conserving for community members, minimizing the regulatory or economic costs of conservation/maximizing regulatory or economic costs of conservation for corporations, etc.

Another way to look at this question is to view it as a question of the flow of information amongst science, management, and policy. How we can use the scientific information we gather to determine the way we manage reef resources? How can the management information we gather determine appropriate policy? What does it take to move from policy to on-the-ground success? And what information do managers need from scientists in order to do their job most effectively?

3. What is the right level at which to formulate policy that really makes a difference?
All too often, the best-intentioned policy efforts do not translate into real changes on the ground. Why is this? A good deal of attention has been paid to this question, so I will highlight just a few points here. First, policy conversations often revolve around maxims whose practical application is not necessarily clear. For instance, one often hears of the need to "adopt the precautionary principle." What should one be "precautionary" about—economic risk? Societal risk? Ecosystem risk? And just

how precautionary ought managers to be? Policy-makers, scientists, and managers often clamor for more data without always specifying how that data would influence policy decisions. Given the pressing need for policies that reduce the negative effects of climate change, we must learn to write policies and make management decisions based on what we know, acknowledging and prioritizing data gaps and crafting policies such that new data can be incorporated in a timely fashion.

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Converting socio-political momentum into conservation action in the Great Barrier Reef. Paul Marshall

In the first years of this decade, Australia, like many nations, was struggling to come to terms with the climate change as an environmental, social and political phenomenon. The issue was distant and dubious in the minds of the public and many decision-makers, despite growing consensus among the scientific community of its significant and urgency. However, by mid-decade the tide had turned, with a rapid ascent of climate change to a confirmed and urgent issue of national importance. Coral reefs played a key role as an agent of change for public and government opinion due to the significance of the Great Barrier Reef in the national psyche and international standing, and the dramatic and worrying impacts of coral bleaching events associated with unusually hot climatic conditions. Lasting and damaging droughts throughout the country, leading to water shortages in major cities, further brought the threat of climate change into the homes and lives of every Australian. At around the same time as people were having these personal experiences with climate-related events, Al Gore's film "An Inconvenient Truth" provided a compelling and accessible knowledge base for people to contextualise their experiences. Riding this wave of new awareness and concern, a new government was elected late in 2007, partly on a platform of climate change reform. The first official task for the new Prime Minister was to sign the Kyoto Protocol.

Coral reefs played a significant role in driving the change in national consciousness and political position. Built on the foundation provided by early observations of mass coral bleaching (in 1998) and a milestone scientific review by Ove Hoegh-Guldberg, detailed monitoring, impact assessment and evolving policy and management responses in Australia have characterised the dramatic increase in awareness about the threat posed by climate change. Key events in Australia include:

- The second major mass bleaching of the GBR occurred in 2002, consolidating concerns that the GBR was not immune from the effects of climate change.
- GBRMPA develops a formal Coral Bleaching Response Plan. This had dual objectives of both monitoring bleaching to understand it better, but just as importantly to improve communications and reporting of bleaching to stakeholders, including tourism industry, policy-makers, politicians and the public.
- Observations of impacts and the drive for an informed policy response lead to coral reef issues being incorporated into the National Biodiversity and Climate Change Action Plan. This gave coral reefs a primary place in the national policy and political landscape with respect to climate change responses.
- With increasing results and demonstration of climate impacts, the coral reef science community (lead by Terry Hughes) developed the "Townsville declaration on climate change and coral reefs", providing a powerful declaration by a group of experts that the GBR was under threat. The statement was broadly reported and circulated among politicians and wider population
- As a result of the above processes, the vulnerability of coral reefs, including the GBR, increased dramatically. Manifestations include prominent attention to coral reefs in the IPCC Fourth Assessment Report and in the Convention on Biological Diversity (CBD)
- The Australian government developed a National Climate Change Adaptation Framework that included support for a five-year Great Barrier Reef Climate Change Action Plan. The GBR Action Plan was funded as a national case study in climate response.

- The Australian government also established a federal Department of Climate Change. Among other activities, the DCC established a Climate Change Adaptation Research Facility to help Australia prepare for climate change by funding science targeted at adaptation.
- Under the National Climate Change Adaptation Framework, the Great Barrier Reef Marine Park Authority established a dedicated Climate Change Group, which has responsibility for leading and coordinating climate change response activities within the Authority. A key contribution of this group has been the compilation of a Climate Change Vulnerability Assessment of the GBR (850 pages), which informed the development of the GBR Climate Change Action Plan

Making climate science relevant to policy: The UK Climate report card. Dan Laffoley

A key challenge in promoting policy development is effectively communicating information on complex issues rapidly and accurately through to policy advisors and decision makers. It is essential to communicate the core message in terms meaningful to wider stakeholders and policy developers in order to reduce the lag time involved in transferring scientific results through to policy action, and in so doing accelerate the growth of awareness and implementation of actions that can be taken to adjust to likely impacts, thus also making a more compelling case for reductions in carbon dioxide emissions. The UK Government addresses the science-policy gap with the Annual Report Card (ARC) on Climate Change, developed by the Marine Climate Change Impacts Partnership (MCCIP) that effectively dissects complex information on real and potential climate impacts, and the uncertainty associated with measuring and predicting them, into a succinct document meaningful to government institutions and decision-makers.

The UK Government has set out a vision for ‘clean, safe, healthy, productive and biologically diverse oceans and seas’, yet as recently as 2005 the UK Government report “Charting Progress: An Integrated Assessment of the State of the UK Seas” was unable to assess the potential impacts of climate change on the UK marine environment. The MCCIP was announced and launched in March 2005 as one of the main actions from this report, which identified climate change and unsustainable fishing as the two main threats facing the UK’s marine environment. The partnership brings together scientists, government, its agencies and NGOs to provide co-ordinated advice to policy advisors and decision makers on climate change impacts around the UK’s coast and seas.

The initial objectives of MCCIP are to:

- Develop and maintain a coordinating framework for marine partners in the UK.
- Build the knowledge base and consolidate evidence of marine climate change impacts.
- Create effective mechanisms for the efficient transfer of marine climate change knowledge from the scientific community to policy advisers and decision makers.
- Facilitate uptake of tools and strategies to assist stakeholders in developing and assessing adaptation strategies.

It is planned that MCCIP will also help to: identify gaps in knowledge and recommend priority areas for future research; assemble community views and partner requirements for climate change tools and information (e.g. marine scenarios of climate change) and advise on the development of an integrated marine climate impacts monitoring programme.

Communicating science through MCCIP

The potential impacts of climate change on our marine environment are extensive and will require a multi-disciplinary scientific approach to address and understand them. MCCIP provides this breadth and acts as the focal point for impacts evidence and advice, assessing the scientific evidence base (via expert review) across all aspects of the UK’s marine environment. The themes explored are consistent with the UK Governments’ vision for clean, safe, healthy, productive and biologically diverse oceans and seas, with topics ranging from sea temperature to seabirds, through to societal implications such as flooding and tourism. The topic of climate change *per se* is high profile and increasingly political and therefore the messages communicated are open to interpretation by interested parties, whether intentional or not. This puts an even stronger emphasis on the MCCIP to provide clear and, where possible, unambiguous messages. MCCIP is currently at an early stage. It will continue to develop over the forthcoming years and it is anticipated that its products will increasingly demonstrate the value of a co-ordinated approach to addressing marine climate change issues.

Building the scientific evidence base

The over-arching challenge for the MCCIP is to assimilate scientific evidence to provide an overall synopsis of marine climate change impacts, placing the results of individual studies into a broad marine ecosystem context that can provide a sound basis for decision-making and policy development or implementation. In comparison with terrestrially focused impacts of climate change, scientific understanding of how climate change will manifest in and impact on the marine environment is limited.

Therefore increasing levels of understanding, via MCCIP, is a priority. The ARC is one of the primary annual outputs of the MCCIP programme, providing a synthesis of developments in UK marine and climate science in the form of a short, comprehensive, quality assured, high level assimilation of knowledge set out in a visually impacting way that enables the results to be quickly and easily understood and used by policy advisors, decision makers, Ministers, Parliament and the devolved administrations.

In November 2006, the Partnership launched its first ARC, providing an at-a-glance summary of current scientific understanding of marine climate change impacts (www.mccip.org.uk/arc). The ARC is based on reviews submitted by leading UK climate and marine scientists on a broad array of subjects, encompassing all aspects of the marine environment. The ARC addresses what we know is already happening, what could happen in the future and rates the scientists' confidence in our current level of understanding. It strongly suggests that climate change has important consequences for biological diversity, cleanliness and safety and the commercial productivity of the UK's seas. MCCIP launched its second marine climate change impacts annual report card on 16th January 2007 at the Scottish Government buildings in Edinburgh. It highlights key developments since the launch of the first report card and explores new subject areas (coastal erosion, coastal habitats and air-sea exchanges of heat and water). It brings together scientific understanding from a wider range of research institutes, providing an even more comprehensive assessment of UK marine climate change impacts and highlights regional variations where possible.

The future

Looking forward, as MCCIP continues to mature, a natural progression will be to begin to apply the lessons we are learning from the MCCIP at European levels. This will help to ensure that the scientific evidence base on marine climate impacts is able to inform emerging and future EU level policy and legislative instruments and influence future domestic legislation of European Member States.

The cost of marine climate change impacts will be borne by all. In spite of uncertainty issues, some consistent observed trends, such as enhanced storminess, increased wave heights and sea level rise are concerning, not least to coastal managers. It is known that sea level rise and potential increases in storm surges and storminess will increase the threat to coastal communities and will be of critical importance for the development of planning strategies. Understanding the nature and scale of these potential impacts and acting upon them represents a huge challenge for us all.

Furthermore, this style of conveying quick key messages, where 'less is more', could also be very useful in policy-making concerning coral reefs, where drastic climate change related degradation is occurring and policy-makers need to be advised of key messages rapidly in order to implement meaningful policies.

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Red Listing Coral Species: Strategies and opportunities to strengthen marine conservation policy and action in the Coral Triangle Region. Kent Carpenter

The world's known 845 species of reef-building zooxanthellate corals (order Scleractinia plus the families Helioporidae, Tubiporidae, and Milleporidae) have been assessed for the first time (Carpenter *et al.* 2008). These reef-building corals are essential habitat for many species of fish and invertebrates making them the most biologically diverse ecosystems in the ocean. Almost one-third of these corals (27% including the 141 Data Deficient species, or 32% excluding Data Deficient species) have been listed in threatened Categories, representing an elevated risk of extinction. Globally, the Indo-Malay-Philippine Archipelago or the "Coral Triangle" has the highest number of species in threatened Categories. This region is also known as the epicenter of marine biodiversity, and has the highest coral species richness.

Primary threats to these reef-building corals are increased frequency and duration of bleaching and disease events that have been linked to the increase in sea temperatures, a symptom of global climate change. A further sinister threat to corals is ocean acidification as a result of increasing levels of atmospheric carbon dioxide, and increased predation by Crown of Thorns Starfish (*Acanthaster planci)*. The impacts of these oceanographic environmental changes are also compounded by anthropogenic threats including coastal development, coral extraction, over-fishing, sedimentation and pollution.

In any region, the potential loss of these coral ecosystems will have huge cascading effects for reef-dependent species, and on the large number of people and nations that depend on coral reef resources for economic and food security. Within the Coral Triangle Region:

- Fully one- third of the inhabitants – more than 120 million people, particularly those living in coastal communities -- depend directly on local marine and coastal resources for their income, livelihoods, and food security.
- The estimated annual value of the coral reefs, mangroves, and associated natural habitats total US $2.3 billion.
- Healthy reef systems and mangrove belts protect coastal communities from storms and tsunamis, reducing casualties, injuries, future reconstruction costs, and the need for international aid.
- Tuna spawning and nursery grounds support a multi-billion dollar (US) tuna industry, providing an important food source for tens of millions of consumers worldwide, and providing thousands of jobs for inhabitants within the region in the fisheries and fish processing sectors.
- Other wild-caught marine products (e.g., snapper, grouper, beche-de-mer, shrimp) are sold to local markets and exported worldwide, generating hundreds of millions of dollars (US) in additional annual revenue, as well as important food sources.
- Productive coral reef systems provide for most of the US $800+ million annual trade in live reef food fish (primarily supplying markets in China).
- Productive coral reef systems also provide for a major share of the trade in live reef aquarium fish and other ornamentals (supplying markets worldwide).
- Healthy marine resources contribute to a growing nature-based tourism industry in the region (e.g., dive tourism), generating tens of millions of dollars (US) annually and thousands of jobs.

The Coral Triangle Initiative is a multilateral and multi-agency initiative. Based on coral and reef fish diversity, it has been defined and adopted by six countries in the region (Philippines, Malaysia, Indonesia, East Timor, Solomon Islands, and Papua New Guinea). The five major points of action include: 1) Designation and Effective Management of Priority Seascapes such as the Papuan Birds Head Seascape and the Sulu-Sulawesi Seascape 2) An ecosystem approach to Management of Fisheries (EAFM) and other marine resources, that includes legislative, policy and regulatory frameworks for sustainable management and improved income 3) Establishment of effectively managed Marine Protected Areas 4) Adaptation of climate change measures and 5) Improvement in the status of designated threatened species.

The pressing need to implement and enforce marine conservation priorities in the CTI region has been further enforced by a back casting exercise using current and pre-1998 data and the Red List Criteria that show that coral species and reef systems were in much better condition than they are today. In sum, the Coral Triangle Initiative is a concrete example of how coral Red List data has spearheaded a multilateral initiative to address and improve marine conservation policies and actions that are tailored to specific threats. The Coral Triangle Initiative will also influence and support the expansion of other related regional and international conservation agendas including for example, CITES and the identification of Key Biodiversity Areas.

Wilderness area protection and sustainable financing in a Small Island Developing State – Kiribati. Greg Stone

In 2008 Kiribati, a Small Island Developing State with a land are of some 100 km^2 and EEZ of over 3.5 million km^2 announced the establishment of the largest Marine Protected Area in the world, covering some 450,000 sq. km. The Phoenix Islands, the central one of three island groups in Kiribati, has been largely uninhabited for several centuries, only supporting temporary populations for decades at a time. Away from the major transit routes across the Pacific, the islands have also been spared frequent visits by fishing boats looking for high value reef products such as sharkfin, lobster and giant clams. However the waters around the Phoenix Islands support tuna fishing, contributing to the government's main source of income and foreign exchange. Kiribati culture places a very high value on the sea, and on fishing and seafaring as a way of life, and the Phoenix Islands are valued by the i-Kiribati for their legendary isolation and pristine condition, a strong contrast to the inhabited islands of the Gilbert group and northern Line Islands.

Starting in 2000, research expeditions run by the New England Aquarium found coral reefs completely free of human impacts, with robust coral populations and super-abundant reef fish reminiscent of a pristine ocean. With repeated visits to the islands, and to meetings with government officials on the main island Tarawa, it became clear this was a unique opportunity to blend the cultural values and pride of Kiribati with the scientific knowledge about the islands to protect them from damage in the future. While this has been a complex undertaking combining the efforts of many people and organizations, at the policy level we can identify 3 key features that made this possible.

1) With little land area, Kiribati values highly its islands and marine ecosystems, with fisheries being a prime income earner. In such a remote location, it became clear that reef fisheries, like most standard uses of the islands, are prohibitively expensive and vulnerable to over-exploitation. The concept of a 'reverse fishing license' came about, that the country could earn sustainable financing from licensing the reef fishery resources NOT to be fished. This provided a mechanism to legislate protection of the islands and reefs and a way to generate funding to keep them pristine. With experience in successfully managing a national endowment fund (from guano-mining in the first half of the 1900s), this has provided an attractive financing vehicle for donations, with staged targets to continue to attract donors in the future.

2) With a strong national cultural identity and pride in the sea, the pristine nature of the Phoenix Islands caught the imagination of government officials and the public. Backed by scientific findings and regular visits by the science team to Tarawa, a DVD video celebrating the reef and island ecosystems, and the lives of the few people living on the Phoenix Islands was produced, and quickly became a favourite for travelling officials, showing it at conferences and exhibitions and building a broader constituency of support for protecting the marine and island ecosystems in the island group.

3) Through regular contact and communication between all partners in the project, a sense of pride and value in the Phoenix Islands and complementary values and contributions strengthened the commitment of all the partners. Starting with the initial scientific surveys and reporting visits to Tarawa, then increasing with more extended stays on Tarawa to contribute to new parts of the growing PIPA initiative, and joint delegations to conferences and conventions involving the highest government officials, the growing rapport among the individuals, government departments and organizations contributing to the PIPA built it up from small and modest beginnings to the largest MPA in the world, in just under 7 years.

The PIPA initiative is an example of policy development that was founded on shared aims and mutual trust among partners, and in a country whose culture shows clear values for the natural environment, how it sustains their culture, and their need to care for it.

An approach to building the human dimension into marine conservation. Nadine Marshall

Background
The management of marine resources, so that they can sustainably provide for current and future generations, is becoming a most urgent issue. Increases in the demand for fisheries products and the impacts of growing world populations on the marine environment have meant that more stringent policies that regulate the use of, or access to, the fisheries resources are imminently required. However, policies are often applied without full knowledge of the capacity of people to cope and adapt to them. Resource managers, policy makers, communities and resource-users alike require prior knowledge of the likely social consequences of their actions if they are to implement acceptable resource-protection strategies and succeed in their conservation endeavours. Marine-protection policies that are introduced without due consideration of people's capacity to cope and adapt can be ineffective in achieving resource protection: not only can they erode the resilience of the very people they are trying to protect; they are typically associated with intense conflict, low compliance, significant delays and overly complicated criteria. The incorporation of knowledge of social resilience into the decision-making process can significantly reduce the uncertainty with which marine sustainability policies are implemented.

This paper outlines how knowledge of social resilience, and its influences, can significantly assist in the policy development process to reduce uncertainty and to ensure that the stress that they place upon individuals, industries and communities does not compromise their ability to adapt and prosper.

Quantifying social resilience and its influences
Social resilience is a multi-dimensional concept comprising of 4 essential components: (i) the perception and management of risk, (ii) the proximity to financial and emotional thresholds, (iii) the capacity to plan, learn and reorganise, and (iv) the level of flexibility within the system as measured by the level of interest in change and the extent to which alternative (and appropriate) livelihood options are available. Standard social science methods can be used to assess these indicators. One of the advantages of quantifying social resilience is that it is possible to statistically examine the influence of other factors on it. An understanding of how social resilience is influenced allows policy makers to further identify vulnerability to institutional change and guide policy development processes.

Resource dependency is one social concept known to significantly influence social resilience. It is a concept describing the nature and extent to which resource-users are dependent on the marine resource. It comprises social components (occupational attachment, attachment to place, employability, family circumstances) economic components (business size, strategic approach, financial situation), and environmental components (level of specialisation, local skills and knowledge and environmental attitudes). Whilst not all aspects of resource dependency will equally influence social resilience in all regions, consideration of each component will allow policy makers to understand how regional differences may manifest themselves and that strategies aiming to maintain or enhance resilience may not be identical across regions. Policy development that can take into account the nature and magnitude of people's dependency on a resource are more likely to maintain social resilience at a local level.

'Policy perception', the process by which policies are developed, delivered and interpreted, has also been shown to be an important influence on social resilience. In order for resilience to be maintained, policies need to be developed in consultation so that they are positively interpreted. Fishers are more likely to accept a policy change if they have been involved in the process because they are more likely to trust the motivation behind it and understand the need for it. They need to trust that the decision was based on sensible information from which they themselves could benefit. Where policy is credible, common goals are achievable and the resilience of the combined social and ecological system can remain intact.

Standard social science methods can be used to assess these concepts. The resultant assessment provides a relative measure of social resilience and enables the nature of vulnerability to be identified (and addressed) so that resources directed at enhancing social resilience can be best targeted for maximum effect.

Key messages

- Social resilience in marine conservation describes the capacity of people to cope and adapt to change in policy.
- Assessing social resilience allows policy makers to assess what the likely response to proposed policy actions might and to identify strategies that minimise the costs of environmental protection.
- These advantages can be amplified with a better understanding of what factors erode or enhance resilience. We know that the level of dependency on a resource and how polices are perceived are significantly correlated with aspects of social resilience.
- Conceptual frameworks and operational tools are emerging that enable social resilience, resource dependency and policy perception to be built into marine conservation. These tools enable major sources of vulnerability to be identified and described (and potentially addressed).
- Policies that reflect social circumstances and vulnerabilities are more likely to maintain social resilience, increase compliance, reduce transaction costs and thus better protect the marine resource.

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The Honolulu Declaration on ocean acidification and coral reef management. Lynne Hale

This paper presents a summary of the findings and recommendations of the "Honolulu Declaration on Ocean Acidification and Reef Management" resulting from a workshop convened by The Nature Conservancy in Hawaii, 12-14 September. Full document available at: http://cms.iucn.org/cccr/publications/

About 1/3 of the CO_2 released to the atmosphere is absorbed by the oceans where it contributes to acidification and a decrease in the aragonite saturation state, which means there is less carbonate available for calcifying organisms like corals to build their skeletons.

If the current emission trend continues, we could see a doubling of atmospheric CO_2 in as little as 50 years; and ocean acidification will continue to an extent and at rates that have not occurred for tens of millions of years.

Ocean acidification is creeping, progressive, and insidious – likened by one workshop participant to osteoporosis of the reef – a weakening of the reef structure that makes corals more vulnerable to breakage from waves and human use.

Because it is harder to see than bleaching, we don't know whether we have reached or surpassed the critical thresholds for any reef species, such as we have for temperature thresholds.

The best evidence we have suggests that when atmospheric CO_2 levels reach 560 ppm, many reefs will already have moved from net growth to net erosion.

Recognizing the potential irreversibility of ocean acidification impacts, it has never been more imperative to improve the management of coral reef ecosystems; and to be both proactive and adaptive in our efforts.

Responding to this challenge, and keen to safeguard its investment in coral reef conservation, The Nature Conservancy convened leading climate and marine scientists and coral reef managers from the US and Australia to chart a course of action to address ocean acidification. Two major strategies emerged:

1. Limit fossil fuel emissions, and
2. Build the resilience of coral reef ecosystems and communities to maximize their ability to resist and recover from climate change impacts, including ocean acidification

Participants identified 7 policy and 8 management recommendations.

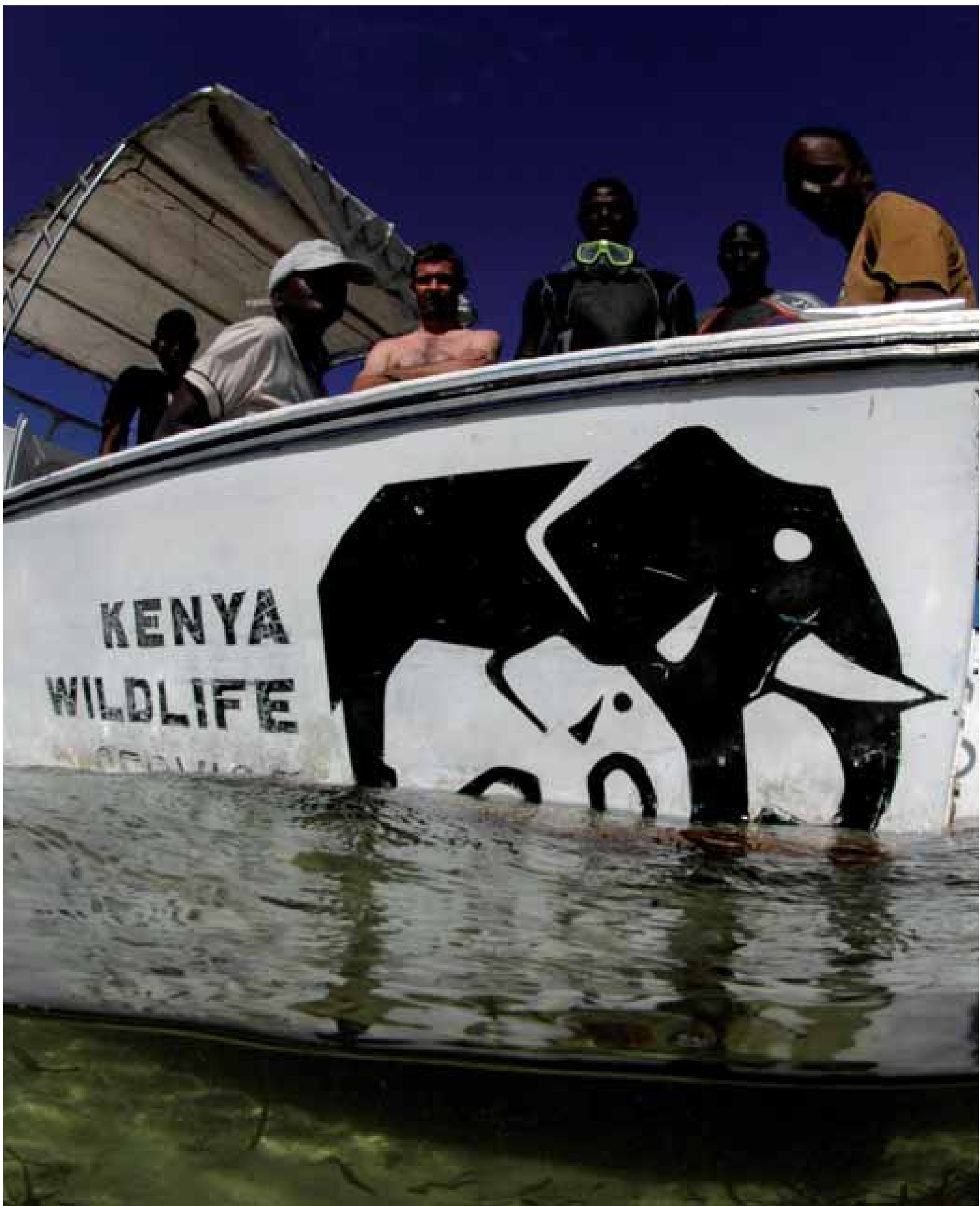
Highlights of the policy recommendations include the need to:
- stabilize CO_2 emissions and reduce marine pollution from all sources – land, sea and sky – especially those contributing to acidification,
- mandate the inclusion of climate change actions into Marine Protected Area management plans, and
- increase appropriations to improve the science and actions addressing ocean acidification impacts on coral reefs

Key management recommendations include the need to:
- reduce all stresses on coral reefs as much as possible to enhance their health and resilience,
- protect reefs that are less vulnerable to the impacts of ocean acidification by creating new marine protected areas, if necessary, and through revision of zoning plans in existing ones,
- implement innovative interventions to reduce damage to weakened reefs and replenish species loss caused by ocean acidification, and
- develop a collaborative international program on ocean acidification that includes a coordinated network of monitoring stations.

While the consequences of inaction are too depressing to contemplate, our workshop generated some good news. We identified some practical steps we can take to buy time for coral reefs while CO_2 levels are stabilized; and that there is hope for coral reefs if we act now.

These recommendations have been submitted in full, along with the Honolulu Declaration and a technical background document that expands on the science and proposed actions, to the US Coral Reef Task Force, and will be integrated into NOAA’s Coral Reef Program.

We respectfully request IUCN and its members to consider our recommendations, to begin to integrate these into their coral reef conservation programs, and for IUCN to report back on progress at the next WCC.



INTERNATIONAL UNION
FOR CONSERVATION OF NATURE

WORLD HEADQUARTERS
Rue Mauverney 28
1196 Gland, Switzerland
marine@iucn.org

www.iucn.org/marine