NOAA Coral Reef Conservation Program 2010-2015
Climate Change and Ocean Acidification Goals and Objectives

Prepared by the Climate Change Working Group June 2009

Introduction to the threats of Climate Change and Ocean Acidification:
Climate change and ocean acidification have been identified by many groups as the most important threat to coral reefs on a global basis. In 2007, the Intergovernmental Panel on Climate Change (IPCC) noted that the evidence is now "unequivocal" that the earth's atmosphere and oceans are warming and concluded that these changes are primarily due to anthropogenic greenhouse gases, especially the accelerating increase in emissions of carbon dioxide (CO_2). While reducing CO_2 and other greenhouse gas emissions is vital to stabilize the climate in the long term, excess CO_2 already in the atmosphere has changed and will continue to change global climate throughout the next century. Global ocean temperature has risen by 0.74°C/1.3°F since the late 19th century causing more frequent and severe bleaching of corals around the world. At the current increasing rate of greenhouse gas emissions, a temperature rise of up to 4.0°C/7.2°F this century is a distinct possibility. These changes have already had deleterious impacts on coral reef ecosystems and will continue to affect coral reef ecosystems globally over the coming century.

At the same time, the ocean absorbs approximately one-third of the additional CO_2 generated every year by human activities making the ocean more acidic (Caldeira and Wickett 2003, Sabine *et al*. 2004). The resulting change to ocean chemistry has important consequences for corals and other marine life, especially other important reef calcifiers. Warming seas and ocean acidification are already affecting reefs by causing mass coral "bleaching" events and slowing the growth of coral skeletons (Hoegh-Guldberg *et al*. 2007; De'ath *et al*. 2009). Bleaching and infectious disease outbreaks are likely to be more frequent and severe as temperatures rise, increasing coral mortality. Climate changes will have other impacts on marine systems such as sea level rise; altered frequency, intensity, and distribution of tropical storms; altered ocean circulation with its effects on larval connectivity and productivity and others. All of these impacts will combine, often synergistically, to eliminate important ecosystem services and reduce global biodiversity.

We can improve the future of coral reefs, but doing so requires action now to reduce the lethal combination of climate change, ocean acidification, and the damaging impacts from land-based sources of pollution and ecologically unsustainable fishing (Marshall and Schuttenberg 2006). Immediate policy and management actions are required if tropical ecosystems are to withstand the impacts of climate change and ocean acidification. Three sets of actions are needed to protect coral reef ecosystems from the effects of climate change and ocean acidification.

- Reduce greenhouse gases. This requires reducing emissions and reducing accumulated greenhouse gases to avoid dangerous, irreversible climate change effects. While regulating emissions falls outside of NOAA's mandate, NOAA has a clear role to monitor climate change and ocean acidification, project their impacts on ecological and human systems, and develop ways to address these impacts that support local, national, and international policy. Unfortunately, we can expect at least another 1°C/1.8°F temperature rise within this century from the greenhouse gases already released. Therefore it is essential that we not only reduce emissions, but take urgent actions to reduce the impact of elevated greenhouse gases on coral reef ecosystems.
- Increase the resilience of coral reef ecosystems to climate change by reducing local stressors including land-based sources of pollution and ecologically unsustainable fishing. We need to identify and address those local stressors that will particularly reduce the ability of reefs to withstand future climate change and ocean acidification.
- Reduce the local impacts of climate change and ocean acidification on coral reefs to help corals and coral reefs increase their ability to survive as these global stressors increase.

These latter two sets of actions fall within NOAA's responsibilities and will help keep coral reef ecosystems intact until greenhouse gas levels are stabilized and reduced to sustainable levels. NOAA and its partners must redouble efforts to reduce local stressors, while monitoring and evaluating their effectiveness at ameliorating the impact of global-scale stressors. In many cases, however, it will not be enough to reduce non-climate stressors, so we will need to take direct action to reduce the stress that climate change and ocean acidification have on reefs at local levels.

To address the problems of anthropogenic climate change and ocean acidification four Goals that must be addressed to help coral reefs cope with climate change. These are:

- Manage for Resilience,
- Address Risks and Vulnerabilities,
- Provide Forecasts and Projections, and
- Intervene to Reduce Climate Stress and Impacts

These goals are presented in a logical sequence but must be addressed simultaneously. Various parts of NOAA and its many partners have made important strides toward monitoring, understanding, and predicting climate change, ocean acidification, and impacts of both on coral reef ecosystems. CRCP will capitalize on existing efforts and build strong partnerships to reduce the impacts of climate change and ocean acidification on all coral reefs, including those in remote locations.

<u>Climate Change Goal 1</u>: Manage for Resilience
Increase coral reef resilience to climate change and ocean acidification through effective management strategies.

Rationale for this goal: The decline and loss of most coral reefs during recent decades is due to a combination of the global pressures of climate change and ocean acidification coupled with regional and local stressors – including cumulative impacts from land-based sources of pollution, ecologically unsustainable fishing, and habitat destruction associated with coastal development. These local stressors act in concert to reduce the resilience of coral reef ecosystems. While mitigating the rate of climate change will largely depend on redirecting national and international policies on green house gas emissions, the ability for coral reefs to survive climate change requires enhancing resilience through local management actions. This approach to resilience underpins effective ecosystem-based management (Levin and Lubchenco 2008). We need to enhance local management to enable the survival of coral reef ecosystems.

Managers need greater support and new tools to protect coral reefs against climate change impacts while they continue to reduce non-climate stressors. New management actions to increase coral reef resilience to climate change must be identified and tested, while existing tools (e.g., watershed/coastal planning, water quality protection, marine zoning) must be improved and applied more effectively to enhance resilience to climate change. However, a lack of local capacity constrains local coral reef management success and this must be addressed to enable timely implementation of management strategies to increase coral reef resilience. Therefore, effectively communicating the clear link between coral reef conservation and human welfare is required to secure stakeholder and legislative support for strengthened and innovative management actions needed to save coral reefs.

The goal *Manage for Resilience* is organized around a comprehensive approach towards maximizing the resilience of coral reefs in US jurisdictions. The objectives under this goal will support coral reef management success to build management capacity and strengthen governance and public support for immediate action to effectively reduce stressors known to weaken reef resilience; implement and evaluate existing and emerging tools to forecast climate change impacts and protect reefs by conferring resilience to impacts; develop place-based crisis response plans; eliminate or overcome regulatory barriers that currently inhibit action; and enable continual integration of scientific advances into applied management strategies. While ecosystem resilience reaches far beyond the issue of climate change, managing non-climate stressors is an important “no regrets” approach to increase the resilience of coral reef ecosystems to the threats of climate change and ocean acidification. Such activities often involve the most direct action local managers and politicians can take and, as such, stand the best chance of success. Finally, it is important for

resource managers to have the information they need to support local, national, and global efforts to reduce greenhouse gases.

Objective 1.1: Provide training opportunities to coral reef managers to increase their understanding of the impacts of climate change, the predicted range and uncertainty of changes that will occur, and management strategies that address the impacts of climate change.

Managers and policy makers need the knowledge and capacity to respond to changing conditions and to take effective actions to increase resilience.

Potential Activities:

- *Increase manager's understanding of the climate change threat [5 year]*
- *Work with managers and scientists to identify region-specific resilience bottle-necks (i.e., those conditions that control the ability to recover) [5 year]*
- *Identify and support implementation of strategic management activities that increase resilience (e.g., target conservation of key herbivores, identify and protect 'sleeper' functional groups) [5 year]*

Objective 1.2: Develop and implement effective local communication plans that provide relevant and up-to-date information on climate change and ocean acidification to stakeholders.

This includes mechanisms to provide needed information to local managers to help them develop strong stakeholder support for local actions, including more effective regulation to increase resilience, and support for local, national, and global efforts to reduce greenhouse gases.

Potential Activities:

- *Develop strategic, long-term communication plans that address broader communication purposes at local, national, and international scales – (i.e., to include what impacts are occurring, how managers are responding and why, what the results are of those management responses, convey limitations on what managers can do, and the role of citizens in responding to climate change) [5 year]*
- *Develop outreach materials and delivery mechanisms that 'make the case' for climate change, resilience-based management, and the necessary management responses that target key audiences (e.g., policy-makers, different community stakeholder groups, and general public) [5 year]*
- *Develop and publicize US and international case studies on impacts of climate change and ocean acidification to encourage greenhouse gas (GHG) reduction [5 year]*

Objective 1.3: Develop and implement climate related crisis response plans in all US coral reef jurisdictions to provide a framework for early warning, communication, monitoring, research, and management response to protect coral reef ecosystems from acute events such as coral bleaching, infectious disease outbreaks, tropical storm impacts, and major rainfall events.

Monitoring change, communicating with stakeholders, and management actions are all needed and require advance planning and strong local support.

Potential Activities:

- *Improve early warning systems for acute disturbances [5 year]*
- *Develop national and local rapid response plans for each US jurisdiction that include a comprehensive communication component and provide a framework for monitoring, research, and management response [start in 5 years]*
- *Partner with emergency management agencies [5 year]*

Objective 1.4: Working with jurisdictions, assess how to improve regulatory and management frameworks to facilitate adaptation to climate change and ocean acidification.

Many resource managers are limited in their ability to address climate change because of existing regulation and legislation. Changing this necessitates enhancing the legal framework and strengthening the political will to act. Actions will be taken to enable policy makers to identify and reduce impediments and enhance constructive approaches to increase resilience of coral reef ecosystems to climate change and ocean acidification.

Potential Activities:

- *Enact new legislation to improve local, state/territorial, and federal regulations to protect coral reefs (e.g., clean water laws, MPA zoning, coastal construction laws/permitting) and managed areas to protect reef communities from non-climate change stressors (e.g., sewage and ecologically unsustainable fishing) [5-10 years]*
- *Identify networks of reefs and associated habitats that are (or have the best potential to become) intact, of high biological value and exhibit a high degree of resilience; protect these from local non-climate change stressors through MPAs and marine reserves designation and watershed management programs. [5 year]*
- *Incorporate resilience-based strategies (e.g., representative/resilient MPA networks, herbivorous fishery management/restriction) into management activities of all US jurisdictions (i.e., both existing and emerging strategies) [5 year]*
- *Use predictive tools to estimate value of management and regulatory actions to increase resilience [5 year]*
- *Evaluate the effectiveness of management and regulatory actions to conserve and protect coral reef ecosystems [5 year]*
- *Enhance the ability of agencies to encourage compliance and enforce regulations, since good regulations that are not enforced have no effects on reefs [start in 5 years]*
- *Support enhanced/increased legislative authority to implement strengthened existing, and new management strategies (e.g., working with Federal agencies to encourage them to require strengthened regulatory*

frameworks at local/territory/state level and also working with state/territorial agencies directly – to influence strengthened policies) [5 year]

Objective 1.5: In collaboration with reef managers, develop, test, and apply the best available science to provide new and innovative tools to help managers prepare and respond to climate change and ocean acidification related impacts.

To take actions, managers need high quality warnings and field-tested responses. Through collaborations between managers and scientists, new products specifically geared to enhance management action will be developed and tested.

Potential Activities:

- *Establish what it means to have an "intact, sustainable coral reef ecosystem" [5 year]*
- *Work with scientists to identify the management implications of their research findings [5 year]*
- *Synthesize relevant literature and scientific findings for management application [5 year]*
- *Develop specific management tools and processes based on relevant science and management successes [5 year]*
- *Develop a simple, scientifically supported, matrix to enable managers to determine if local reefs are over-harvested, overused, or otherwise unsustainable, and develop tools to assist with identifying requirements and goals for recovery [5 year]*
- *Develop process to encourage dialogue between managers and scientists to identify priority science [5 year]*
- *Develop methods* to *encourage management action on threats identified by relevant scientifically robust research to ensure adequate compliance and enforcement [5 year]*

<u>Climate Change Goal 2</u>: Address Risks and Vulnerability
Identify, understand, and communicate risks and vulnerability of US coral reef ecosystems, ecosystem services, and dependent human communities to climate change and ocean acidification.

Rationale for this goal: Monitoring the stressors and responses of reefs to global climate change and ocean acidification are essential to assess and document the vulnerability of coral reef ecosystems. This requires characterization of changes in the physical and chemical state of the environment and the responses of coral reefs to these changes from organismal to ecosystem scales. Knowledge of ecosystem vulnerability can then be used to understand the vulnerability of dependent human systems and to assess the risks inherent in various potential emissions targets. While other parts of NOAA and the Federal government will monitor climate change at large spatial scales, monitoring impacts to coral reef ecosystems likely will fall on the CRCP to implement.

Objectives within the *Address Risks and Vulnerability* Goal focus on clearly understanding and describing the changes occurring in the physical and chemical environment, responses of coral reef ecosystems in the face of these changes, and the effects on and responses of human communities dependent on reef resources. These activities provide the baseline knowledge and monitoring to validate predictive assessments of climate change impacts and evaluate management strategies in support of the other climate change goals. They also generate the documentation necessary to support management action to reduce impacts of climate change and ocean acidification and develop new management frameworks to apply in areas that are particularly resilient or vulnerable to these changes. Finally, they provide clear assessments of changes and impacts and identify thresholds needed to predict future impacts.

<u>Objective 2.1</u>: Characterize physical and chemical changes in coral reef environments by enhancing question-based monitoring to fill gaps in our current observations. This both establishes a baseline to assess climate change impacts on coral reef ecosystems and reveals changes through time.

> Managers will not be able to act without evidence of environmental changes that identify the extent of threats. While other parts of NOAA and the Federal government will monitor at large scales, monitoring changes within coral reef ecosystems likely will fall on the CRCP to implement.

<u>Potential Activities:</u>

- *Establish physical and chemical baselines and thresholds including spatial and temporal variability at key sites [5 year]*
- *Gap analysis of existing physical and chemical monitoring programs within the context of climate change [5 year]*
- *Develop new tools needed to better assess environmental changes and their potential impacts [5 year]*
- *Define criteria and identify priority sites [5 year]*

- *Expand coral reef monitoring as necessary to include observations of the physical and chemical environment that influence coral reef ecosystems identified as missing in gap analysis [5 year]*
- *Coordinate with inter-agency, local, national and international programs for monitoring environmental change [long term]*

Objective 2.2: Characterize the responses of coral reef ecosystems and their related components to climate change and ocean acidification to separate impacts from climate change and ocean acidification from impacts of other environmental threats and to text the effectiveness of management actions.

Detailed observations of changes from organisms to ecosystems will provide the information needed to develop forecasts, identify appropriate management responses, and test the effectiveness of both.

Potential Activities:

- *Establish biological and ecological baselines including spatial and temporal variability at key sites [5 year]*
- *Gap analysis of existing biological monitoring programs within the context of climate change [5 year]*
- *Define criteria and identify priority sites [5 year]*
- *Expand coral reef monitoring as necessary to include observations of biological and ecological responses to climate change [5 year]*
- *Identify the current state of knowledge of threshold responses and relevant relationships between coral reef organisms and climate change stressors [5 year]*
- *Develop a set of coral reef health indicators (of symptoms) related to climate change [5 year]*
- *Use these indicators to measure response to changes in physical and chemical status over time [long term]*

Objective 2.3: Characterize socioeconomic effects of climate change impacts on coral reef ecosystems to identify vulnerable reef-dependent human communities and understand the impacts to these communities.

We will both develop our ability to forecast impacts of climate change on human systems and to monitor impacts as they occur. By understanding how climate change impacts influence human systems, we will better understand the cost of action and inaction to mitigate greenhouse gases and adapt to impacts.

Potential Activities:

- *Identify vulnerable human communities in order to communicate levels of risk [5 year]*
- *Establish socioeconomic baselines at key sites against which to measure future change [5 year]*
- *Establish socioeconomic indicators (behavior, resilience, adaptation and maladaptation) of human responses to coral climate impacts on coral reef [5-10 year]*

- *Identify socioeconomic impacts or costs associated with climate change (e.g., sea level rise) impacts on coastal communities [5 year]*
- *Gap analysis of existing socioeconomic programs within the context of climate change [5 year]*
- *Define criteria and identify priority sites [5 year]*
- *Coordinate with existing socioeconomic monitoring programs [long term]*

Objective 2.4: Promote conservation of coral reef ecosystems through identification of areas that are potentially resilient to climate change and vulnerable areas where actions are likely to increase resilience. Encourage and promote management actions necessary to avoid or minimize impacts and spread risk due to climate change and ocean acidification.

It is not enough to observe the changes in coral reef ecosystems in response to climate change. The CRCP must provide options to local managers to respond and improve the ability of coral reef ecosystems to weather these changes. The CRCP will establish criteria through which managers can evaluate the potential vulnerability and resilience of coral reef ecosystems to climate change and ocean acidification, use the monitoring discussed above to identify resilient and vulnerable sites, and recommend the best course of action to maximize resilience in coral reefs under their jurisdiction. Sites will be given priority for action at reefs that are especially resilient or, if especially vulnerable, where threats to resilience are believed to be most manageable.

Potential Activities:

- *Define criteria necessary to identify vulnerability and potential resilience to climate change in coral reef ecosystems making use of existing knowledge as well as new data generated by previous goals as available and appropriate [5 year]*
- *Assess all US Coral Reef jurisdictions to identify locations for establishing ARCCs using input from local, scientific, and management communities [5-10 years]*
- *Provide a suite of management actions that can be taken in these ARCCs [5 year]*

Objective 2.5: Provide and communicate regular national comprehensive risk assessments regarding the threat of climate change and ocean acidification to coral reefs and dependent human communities through relevant, existing reports such as local, national, and global reef status reports and IPCC assessments.

Information on climate change and ocean acidification and their impacts will identify reef areas most at risk and communicate the need to mitigate climate change. Assessments of risk to coral reefs are needed in such reports (e.g., *State of Coral Reef Ecosystems of the US*, *Status of Coral Reefs of the World*, and *IPCC Assessment Reports*, etc.) to support local actions to enhance reef resilience and to engender support for local, national, and global efforts to reduce greenhouse gases.

Potential Activities:

- *Greater representation of risk to coral reefs in IPCC Working Group II Assessments [5 year]*
- *Provide climate change risk assessments to the US State of the Reef Report and Global Coral Reef Status Report, and global socio-economic status report [5 year]*
- *Use risk assessments to communicate to the public and policy makers the need to mitigate climate change and reduce impacts [5 year]*
- *Encourage and facilitate regular communications between local managers and federal experts to address critical questions, influence coral reef grant funding, and assess effectiveness of local management actions and resource conditions [5 year]*

<u>Climate Change Goal 3</u>: Provide Forecasts and Projections
Enhance strategic management of coral reef ecosystems through improved and applied understanding, forecasts, and projections of climate change and ocean acidification impacts.

Rationale for this goal: Information from the climate modeling community continues to improve and is increasingly applicable to questions at finer scales. For this information to be helpful to managers and decision-makers concerned with coral reef ecosystems, these forecasts must be provided in ways that are applicable and at levels of local relevance. Despite the current knowledge of climate change impacts to coral reef ecosystems, the coral reef management community has not effectively integrated or applied these forecasts or used them to provide information needed for decision-making. This will require a concerted effort to couple climate scenarios issued at fine spatial scales with ecosystem responses, and preferably with coral reef ecosystem models.

Activities within the *Provide Forecasts and Projections* Goal will improve the way that state-of-the-art climate modeling forecasts and projections are prepared and delivered so that they provide information needed for coral reef ecosystem management decisions and assessments of future risk. This will require enhanced collaboration between coral reef managers and scientists and the climate modeling community to model future stresses and the response of coral reef ecosystems and dependent human communities. Such integration will also require a greater understanding and modeling of the response of coral reef organisms, ecosystems, and dependent communities than currently exists. Once available, enhanced, high-resolution climate information will be translated into useable products from which coral reef managers and policymakers can plan and make strategic decisions. By anticipating stresses on coral reef ecosystems, managers can make pro-active and sound management decisions to minimize negative impacts on both reefs and human communities. Finally, this will provide clear guidance for policy makers to determine risks and costs involved in various future emissions targets and will hopefully encourage reduction of atmospheric greenhouse gases.

<u>Objective 3.1</u>: Collaborate with climate modeling groups to assess and advise development of physical and chemical models at spatial and temporal scales appropriate to inform management decisions.

This is necessary to assure that the output of climate models provide the necessary input to assessments of the response of coral reef ecosystems and dependent human communities.

<u>Potential Activities:</u>

- *Improve capabilities for short term forecast of climate change stress to aid in management decision making [5 year]*
- *Establish projections to compare with future observations [5 year]*
- *Gap analysis on current observations [5 year]*

- *Interact with the modeling community to ensure we receive the correct information [5 year]*
- *Develop scenarios projecting future impacts of climate change and ocean acidification [5 year]*

Objective 3.2: Through process studies and modeling, develop integrated impact models of changes in coral reef ecosystems in response to the physical and chemical processes associated with climate change and ocean acidification, and the interactions of these processes with local stressors.

Management and policy decisions on climate change and ocean acidification require accurate, meaningful assessments of the threats to coral reef ecosystems. This will require new efforts to develop integrated models and improvements in our understanding of fundamental responses of organisms and ecosystem processes to build these models. Further improvements of our understanding of organismal to ecosystem responses to these stressors are needed to assure that these impact projections are accurate and meaningful.

Potential Activities:

- *Conduct experiments on thermal and chemical effects on representative organisms at multiple life stages and multiple responses (disease, bleaching, calcification, reproduction, etc) (direct effects) [start in 5 years]*
- *Conduct experiments on how thermal and chemical effects interact with other stressors. (indirect effects) [start in 5 years]*
- *Conduct experiments on how thermal and chemical changes influence responses such as bleaching and disease [start in 5 years]*
- *Identify partnerships with other agencies and groups to accomplish the necessary research [5 year]*
- *Model species interaction [5 year]*
- *Conduct mesocosm experiments to look at community interactions [5 year]*
- *Conduct large scale field and natural experiments [5 year]*

Objective 3.3: Forecast and project climate change and ocean acidification related impacts on reef-dependent social and economic systems. Coupling of physical, chemical, ecosystem, and socioeconomic models will be required to project future impacts.

Potential Activities:

- *Work with social science portion of CRCP to better understand and communicate human dependence on coral reefs [5 year]*
- *Determine the economic value of predicted coral reef loss due to climate change and ocean acidification [5 year]*
- *Project future vulnerability of reef dependent human communities in order to communicate levels of risk [5 year]*

Objective 3.4: Translate climate forecasts and projections into products that are relevant and useable for improved coral reef ecosystem management and decision-making.

The management community must be involved to assure that model results address management needs and are communicated in ways that managers and decision-makers can use them.

Potential Activities:

- *Establish dialogue between science and management to identify key needs in forecasting climate change impacts (products) [5 year]*
- *Improve forecasts and projections in both accuracy and utility [5 year]*
- *Understand and communicate the implications of climate change and ocean acidification for management of related ecosystems [5 year]*
- *Integrate the results of above objectives as they are available into new and improved products [long term].*

<u>Climate Change Goal 4</u>: Intervene to Reduce Climate Stress and Impacts
Support management efforts to increase survivorship of coral reef species and enhance reef resilience by evaluating and implementing promising intervention strategies that directly reduce climate change and ocean acidification impacts.

Rationale for this goal: Currently reef managers have little direct control over global-scale stressors (primarily rising temperatures and CO_2 levels) threatening coral reef ecosystems. Additionally, we will have to face the global climate change that will result from the elevated greenhouse gas levels already in the atmosphere. As a consequence, coral reef ecosystems will suffer significant climate change and ocean acidification impacts even if reefs are well managed in all other respects and the international community acts quickly to reduce greenhouse gas emissions. As climate change and ocean acidification impacts continue, there will be an increase in the value of remaining reef populations and species, and an increasing need to maximize resilience at key locations. Although necessarily limited in their scope, intervention actions are merited in certain cases, such as on reefs that contain particularly valuable or threatened species or populations, or that have a high relative abundance of large reproductive colonies.

This goal supports direct efforts (including geoengineering and assisted adaptation or migration) to maximize survivorship and resilience on reefs affected by climate change and ocean acidification. The *Intervene to Reduce Climate Stress and Impacts* Goal begins by testing and evaluating proposed intervention approaches – moving ideas from the lab to the field - and helps establish potential thresholds at which intervention may be merited. Through an interactive process tools will be developed that allow resource managers to identify intervention measures that may be practical for their sites. Approaches that make sense in one locale may be totally inappropriate in another, and different reefs will vary in their vulnerability to global change stressors. Finally, it supports implementation, monitoring, and evaluation of these intervention measures at sites selected as particularly resilient or with potential to become more resilient through intervention.

<u>Objective 4.1:</u> Facilitate the identification, development, and testing of intervention measures to reduce stress from climate change and ocean acidification on coral reef ecosystems in field settings.

> Through careful testing, potential intervention measures can be evaluated for their applicability in real-world settings, moving ideas from the laboratory to field tests. Testing and evaluation will be required before many managers will consider implementing intervention measures. Conversely, managers are key to identifying appropriate field settings to evaluate new techniques.

<u>Potential Activities:</u>

- *Support the development and evaluation of intervention measures designed to reduce climate change and ocean acidification impacts, including but not limited to,* in situ *environmental control; enhancing evolutionary adaptation by propagating or promoting stress tolerant genotypes; and enhancing coral recruitment and succession [5-10 year]*
- *Use predictive tools to evaluate the likely success of management intervention measures [5 year]*
- *Produce progress report on development [5 years]*

Objective 4.2: Work with managers to provide objective tools to evaluate the effectiveness, applicability, and feasibility as well as the potential negative impacts of intervention measures (i.e. develop an intervention toolkit).

Each coral reef ecosystem is as unique as is its management setting. Test of intervention measures will be evaluated and provided to managers for consideration at their sites. By equipping and training resource managers on potential intervention measures, managers can make wise decisions on the feasibility of implementation.

Potential Activities:

- *Identify appropriate sites for larger scale field testing and implementation [5 year]*
- *Evaluate potential negative consequences of intervention measures [5-10 year]*
- *Develop and periodically update list of potential strategies [long term]*
- *Evaluate relative feasibility of implementation [5-10 year]*
- *Produce progress report on testing implementation and results [5 years]*

Objective 4.3: Support implementation and monitoring of promising intervention measures to reduce the impact of climate change and ocean acidification on coral reef ecosystems and evaluate the success of intervention measures (e.g. shading, pumping in cool water, local reduction of acidification, etc.).

Most management agencies lack the financial and technical resources to implement intervention measures on their own. High priority sites will be matched with high-potential intervention methods to reduce the impact of climate change and ocean acidification locally. Intervention measures will be considered for inclusion in the suite of actions taken in areas potentially resilient to climate change.

Potential Activities:

- *Build capacity and provide training for implementation activities [5-10 year]*
- *Promote implementation through targeted communication [5 year]*
- *Establish or improve facilities to implement intervention strategies [5 year]*
- *Evaluate the effectiveness of management actions to conserve and protect coral reef ecosystems [long term]*

Definitions

Adaptation: Adjustment in human and natural systems in response to actual or expected environmental changes (from IPCC not to be confused with evolutionary adaptation).
Climate Change: Any change in the ocean-atmosphere climate system over time, whether due to natural variability or human activity.
Climate Forecasts: The result of an attempt to produce an estimate of the actual trend or variability of climate in the future (e.g., at seasonal, inter-annual or long-term time scales).
Climate Projections: In contract to climate forecast, the calculated response of the ocean-atmospheric climate system to scenarios of emissions or concentration of greenhouse gases and aerosols, or of radiative forcing, often based on simulations by climate models.
Ecosystem Services: The benefits people obtain from ecosystems. These include provisioning services such as food; regulating services such as flood control and shoreline protection; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept "ecosystem goods and services" is synonymous with ecosystem services (adapted from: Millennium Ecosystem Assessment, 2005).
Indicators: An observable, measurable response to change in a specific environmental parameter.
Intervention Measure: An activity or set of activities designed to directly reduce the impact of stressors on coral reef health, usually over small spatial scales (tens of m^2 to hectares).
Ocean Acidification: A measurable reduction in ocean pH caused by increased concentrations of CO_2 in seawater. One result is a reduction in the availability of carbonate ions that marine organisms use to build shells and skeletal structures.
Resilience: The capacity of a system to absorb stresses and continue functioning (Levin and Lubchenco, 2008).
Risk Assessment: Frequent assessment that integrates the potential impacts posed by climate change to coral reef ecosystems and their dependent human communities, the probability of those impacts increasing in the future, and the vulnerability of those communities (coupled with regional and local stressors like pollution, ecologically unsustainable fishing, and habitat destruction) to determine reef areas and populations most at risk.
Threshold: The level of magnitude of a system process at which sudden or rapid change occurs.
Vulnerability: The degree to which a system is susceptible to, and unable to cope with, adverse impacts of stressors. Vulnerability is a function of the character, magnitude, variability, and rate of climate change to which a system is exposed, its sensitivity, and its adaptive capacity.

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Appendix 1:

Education/Outreach/Communication Goals to help inform the Education, Outreach and Communication Working Group Process.

Goal 1: Increase awareness and understanding at all levels of society (policy makers, media, educators, stakeholders, general public) of the impacts of non-climate change stressors on coral reef communities and the synergistic negative effects these stressors can have on reef communities when coupled with climate change stressors.

Goal 2: Evaluate the existing and ongoing education, public awareness and outreach activities to elucidate why, on a broad scale, it appears that the general public, policy makers, and government leaders are not taking adequate steps to address this issue. Is it apathy? Is it lack of knowledge/information? Is it that they feel overwhelmed or that this issue does not merit the attention we're requesting?

Goal 3: Involve local stakeholders in the management process at as many levels as possible. This could include input into initial discussions regarding the size and location of marine protected areas, monitoring activities, enforcement of regulations, or education campaigns.

Goal 4: Increase and enhance citizen stewardship in coastal climate change issues.
While local resource managers provide educational outreach programs, a substantial disconnect in communication among local citizens and resource managers still remains. Many resource management decisions do not fully consider impact to local citizen needs nor adequately engage local citizens in decision processes. This goal would establish programs to facilitate and promote communications among local resource managers and citizens to promote and enhance community stewardship.

> Objective: Enhance and establish educational outreach programs aimed not only at students, but adult local citizens and community interest representatives (particularly resource stakeholders). Pro-active educational events, outreach programs, information seminars, stakeholder visits targeted at local citizens.
>
> Objective: Facilitate development of citizens advisory panels (CAPs) or consultancy panels (CCPs) that are engaged by resource management agencies in the decision making process.
>
> Objective: Establish citizen volunteer programs particularly as can be linked with Goal 1.

Goal 5: Increase public awareness of the sometimes abrupt effects of climate change on ecosystems*. Strategy: Emphasize the role of coral reefs as ecosystemic indicators of climate change. We risk further ecosystemic collapse (including terrestrial ecosystems) if we fail to heed the warning that coral reefs provide (one striking example is the abrupt desertification of the Sahara 5,500 years ago).* Example objective/deliverable: Increase involvement of volunteer divers in bleaching monitoring/ Bleach Watch ground-truthing.

Goal 6: Develop an outreach strategy to educate the public, managers, policy makers and key stakeholders on linkages between climate change and degrading coral reefs and identify feasible actions various constituents can take to improve our understanding of climate related impacts and to mitigate climate change.