NOAA Coral Reef Conservation Program
Strategic Goals and Objectives Public Comment Opportunity

The CRCP is providing an opportunity for public comment on the *Draft NOAA Coral Reef Conservation Program FY 2010-2015 Threat-Based Goals and Objectives* as developed by each of the three threat-based working groups and the International Working Group. Please note that the *Draft NOAA Coral Reef Conservation Program FY 2010-2015 International Goals and Objectives* are included in a separate document. These documents are available for public comment from March 27 – April 24, 2009. Comments will be forwarded to the appropriate working group for their consideration. The final document will be made public in early June.

Public Comment Submission Guidelines

To ensure your comments are submitted in a consistent and useable format, (to the greatest extent possible) please follow the guidelines below:

- Submit comments via email to: crcp.roadmap@noaa.gov
- Indicate in the email subject line, which focus area your comments address. For example RE: International, RE: Climate Change; RE: General Comments. This will help us to better direct and address your comments.
- Please do not provide comments using the Track Changes feature.
- Provide comments based on the **PAGE #** and **LINE #** if addressing a specific section of the document. A comment form is available for your convenience at: www.coralreef.noaa.gov/wgroups/resources/comment.html

PAGE #	LINE#	COMMENT
4	152	Objective does not adequately address ……

The CRCP is looking for comments specific to the draft Goals and Objectives. The sections highlighting *Potential Activities* are included to provide context for the overall Goals and Objectives and are not intended to commit the CRCP to these specific actions at this time. The actions included are for contextual purposes only.

When providing comment, we are particularly interested in the following:

- Are the Goals and Objectives at the appropriate scale (20-year Goals and 5-year Objectives)?
- Are there significant gaps?
- Are the Goals and Objectives sufficiently focused to achieve measurable improvement in coral reef ecosystem condition?
- Identify which objectives you feel should be the top priority for the CRCP.

Dates

Public comments may be submitted from March 27, 2009 through April 24, 2009. The CRCP will not individually respond to those who provide comments. Comments will be forwarded to the appropriate working group for consideration in developing the final Goals and Objectives documents.

Addresses

You may submit comments electronically via e-mail to crcp.roadmap@noaa.gov.
To submit your comments in writing or for further information contact:
CRCP Roadmap Comments
NOAA
1305 East-West Highway, Sta. 10405, (N/ORM)

EXAMPLE

go to: www.coralreef.noaa.gov/wgroups/resources/comment.html

NOAA CRCP Roadmap Threat-Based and International Working Group Public Comment Submission Template

Personal Information (not required)

Name:

Affiliation:

Email:

Focus Area (please choose the most applicable for each separate comment):

General

Fishing Impacts

Land-Based Sources of Pollution

Climate Change

International

Comments

Focus Area	Page #	Line #	Comment

Draft NOAA Coral Reef Conservation Program
FY 2010-2015 Threat-Based Goals and Objectives

Introduction

NOAA's Coral Reef Conservation Program (CRCP) was established in 2000 to help fulfill NOAA's responsibilities under the Coral Reef Conservation Act (CRCA) and Presidential Executive Order 13089 on Coral Reef Protection. The primary goal of the CRCP is to protect, conserve, and restore coral reef resources by maintaining healthy ecosystem function.

In 2007 the CRCP solicited an external review to assess the program's effectiveness in achieving its mandates and provide recommendations for improving its impact and performance. In response to the panel's recommendations and new program leadership, the CRCP has developed a *Roadmap for the Future* to set the program's direction for FY 2010-2015 and lead the CRCP toward a more focused set of priorities. This *Roadmap* builds upon the program's existing goals and objectives, the *National Coral Reef Action Strategy* and other previously developed plans to address threats, improve management, and reverse the degradation and loss of coral reef ecosystems.

The primary objective of the CRCP is to address strategic coral reef management needs in a targeted, cost-effective and efficient manner. To make the most of limited resources and to have the largest impact to reverse general declines in coral reef health, the CRCP will narrow the focus of its national program and shift allocation of CRCP resources to taking on-the-ground and in-the-water action. The CRCP will partner with the coral reef management community to address their strategic needs, and place increased emphasis on place-based management and strategic planning. To narrow its range of activities, the CRCP will emphasize efforts on understanding and addressing the top three global threats to coral reef ecosystems:

- Fishing impacts
- Land-based sources of pollution
- Climate change

Additionally, the CRCP is expanding its international presence by becoming more actively involved in coral conservation efforts primarily in the Pacific, the Coral Triangle region, and the Caribbean.

To best identify the strategic goals and objectives for each of these three threats, the CRCP engaged its community of partners through the formation of four working groups (one per threat) plus an international working group. Each working group has a diverse membership of NOAA staff, other federal agencies, academia, non-governmental organizations, and coral reef jurisdiction representatives, which is intended to draw on a wide breadth of experience and expertise. The working groups have been charged with providing recommendations on the twenty-year strategic goals and five-year objectives the CRCP should work towards to effectively address each of the top three threats to coral reefs, both domestic and international. The CRCP is committed to refining its performance and efficiency measures to

reflect the new program direction and better evaluate overall CRCP performance, placing greater emphasis on outcomes rather than outputs.

As stated in the *Roadmap for the Future*, a key underlying principle of the CRCP is to implement its objectives through strong partnerships. The CRCP recognizes the essential role of and contributions by our myriad partners in effectively addressing the threats facing coral reef ecosystems and have designed the process to develop the CRCP strategic Goals and Objectives to take advantage of this community. The Goals and Objectives outlined in this document reflect the collective view from each working group of what the top priority needs are to address the threats of fishing impacts, land based sources of pollution and climate change. These Goals and Objectives are not intended to commit other agencies or partners to implementing the identified action or to meeting the specific performance measures. However, it is clear that we cannot hope to accomplish our goals without collaboration with partners. This document provides the NOAA CRCP strategic guidance on the program priorities for FY 2010-2015 and implicitly commits the CRCP to work with other agencies and partners to facilitate implementation of the Goals and Objectives herein.

Multidisciplinary Integrated Approach

The CRCP management and its three threat-based working groups recognize that issues beyond Land-based Sources of Pollution, Impacts of Fishing, and Climate Change create challenges in the management of coral reef ecosystems. Conservation of coral reefs will prove most successful only if certain overarching issues are recognized and addressed.

Lack of capacity currently constrains local coral reef management success and must be addressed to enable timely implementation of strengthened existing and new management strategies to increase coral reef resilience. This lack of capacity includes not only adequate staffing, facilities, funding and technical capacity, but also legislative authority and enforcement. While new management actions are identified in the following Goals and Objectives, existing tools including watershed and coastal planning, water quality protection and marine zoning must be strengthened and applied more effectively. Coral reef conservation should be strongly linked to human welfare (e.g., tourism, livelihoods, food security, cultural and spiritual well being) through effective communication. This connection between reef and human welfare will be required to secure stakeholder and legislative support for strengthened and new management actions needed to save coral reefs.

The individual working groups identified similar needs or means of addressing the issues across the three threats. For example, each working group has identified the need for consistent and comparable monitoring efforts across jurisdictions. This includes developing agreed upon metrics that enhance holistic assessment of coral reef ecosystem condition, coordinated across threats. The working groups also identified the need for strengthened and more targeted education, outreach, and communication activities, which will be further developed by a CRCP Education, Outreach and Communications Working Group. The CRCP is committed to examining where these and other overlaps occur and implementing a holistic program that recognizes the potential synergies in both the impacts from the threats

and our actions to address these threats. The CRCP will work to align the final Goals and Objectives during implementation of the program.

Definitions

Adaptation: Adjustment in human and natural systems in response to actual or expected environmental changes.

Areas Resilient to Climate Change (ARCC): A network of reefs and associated habitats that are, or have the best potential to become intact, are of high biological value, exhibit a high degree of resilience or are vulnerable but important to conserve. An ARCC differs from an MPA in that it does not necessarily confer protection, but provides a location to test a broad suite of actions that can be taken to address climate change impacts.

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: 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.

Indicators: An observable, measurable response to change in a specific environmental parameter by a biotic component of an ecosystem.

Intervention Measure: An activity or set of activities designed to directly reduce the impact of climate change and/or ocean acidification stressors on coral reef health, usually over small spatial scales (tens of m^2 to hectares).

Marine Protected Areas: Any area of the marine environment that has been reserved by federal, state, tribal, territorial, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein. (Federal Definition: Executive Order 13158, May 2000)

Marine Reserve: Marine Protected Area in which some or all extractive activities are prohibited.

Ocean Acidification: A measurable reduction in ocean pH caused by increased concentrations of CO_2 in sea water that reduces the availability of carbonate ions that marine organisms use to build shells and skeletal structures.

Resilience: The amount of change or disruption that is required to transform a system from being maintained by one set of mutually reinforcing processes and structures to a different set of processes and structures.

Risk Assessment: Frequent assessment (3-5 years) that integrates the magnitude of observed impacts, the probability of those impacts increasing in the future, coupled with regional and local stressors (e.g., pollution, ecologically unsustainable fishing, and habitat destruction) and socio-economic factors to provide a comprehensive vulnerability assessment of reefs and their dependent human communities to determine reef areas 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 effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Fishing Impacts Working Group
Strategic Goals and Objectives

Rapid human population growth, demand for fishery resources, use of more efficient and destructive fishery gear, and inadequate management and enforcement have led to the depletion of key reef species and habitat damage in many locations. Though coral reef fisheries are usually small in scale, the impacts incurred by coral reef ecosystems are often tremendous. Generally, fishing impacts on reefs include the: 1) direct overexploitation of fish, invertebrates, and algae for food and the aquarium trade; 2) removal of a species or group of species impacting multiple trophic levels; 3) by-catch and mortality of non-target species; and 4) physical impacts to reef environments associated with fishing techniques, fishing gear, and anchoring of fishing vessels (Waddell 2005). Such threats are exacerbated when coupled with other anthropogenic stressors to coral reefs such as climate change and land-based sources of pollution.

In *State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*, local experts identified fishing as a high threat in every populated U.S. jurisdiction except the Commonwealth of the Mariana Islands (CNMI), where it is categorized as a moderate threat (Waddell 2005). The States, Territories, and Federal members of the U.S. Coral Reef Task Force identified fishing in 2002 as one of five key threats to address through local action strategies. Furthermore, CRCP's *Roadmap for the Future* prioritizes Impacts from Fishing as one of three major threats to be addressed. The following Goals and Objectives are recommendations put forth by the Fishing Impacts Working Group to guide the direction of the CRCP's efforts. The CRCP recognizes the value of past and ongoing work to reduce impacts from fishing and seeks to strategically build upon it.

Minimizing negative fishing impacts throughout coral ecosystems is critical to revitalize and protect coral reef resources. Strategic and effective management throughout U.S. jurisdictions must initiate and support processes that measurably reduce coral reef ecosystem degradation thus preserving coral reef ecosystems for current and future generations. The CRCP aims to support and collaborate with Federal, State, Territory, Commonwealth, local, academic and non-governmental "in-the-water" efforts to fully implement the activities outlined below. Cooperation among partners will be essential to monitor and manage living resources across their entire geographic range and to implement the most effective management regimes to prevent and mitigate negative impacts of fishing on coral reefs.

<u>Fishing Impacts Goal 1</u>

Increase the abundance and average size of key coral reef fishery species to protect trophic structure and biodiversity and improve coral reef ecosystem condition.

Excessive fishing may reduce fish size, abundance, and change species composition throughout coral reef ecosystems. This can be severe enough to compromise the natural ecological balance of the system (Bellwood *et al.* 2004). Studies suggest that when key functional reef species, such as herbivorous fishes, are overfished, associated phase-shifts from high-diversity coral-dominated systems to low-productivity algal-dominated communities can occur (Hughes 1994). Shifts in community structure may cause reefs to be

less resilient to other hazardous events including coral bleaching and disease (Westmacott *et al.* 2000). Management, research and monitoring of fishing impacts is challenging due to the diversity of coral reef ecosystem species, the variety of methods used to extract them, and the paucity of basic information on fishing effort and ecology. Thus the intent of Goal 1 is to focus sound science and ecosystem-based management on key species or functional groups.

In addition, Goal 1 seeks to balance the desire for short-term fishery yield with the need for long-term fishery sustainability and coral reef persistence. Reducing impacts from fishing can enhance coral reef integrity, stability and aesthetics by increasing the abundance and average size of targeted species, restoring biodiversity, and maintaining coral reef ecosystem function. When fishing impacts are sufficiently reduced, coral reef ecosystems have the capacity to deliver ecological services while ensuring long-term reef productivity and persistence.

Objective 1.1: Prioritize key coral reef associated species or functional groups (e.g. herbivores, apex predators, etc.) on which to focus management, research and monitoring activities for each jurisdiction.

Objective 1.2: Obtain essential life history and ecological information on key species or functional groups to support management actions that reduce impacts of fishing and improve coral reef ecosystem condition.
(Potential activities include: Identify gaps in knowledge of key coral reef ecosystem species/groups; identify sources of existing information; develop a research plan for filling critical gaps; implement research plan; provide information to managers)

Objective 1.3: Obtain necessary information on fishing effort in coral reef ecosystems in CRCP jurisdictions by measuring fishing intensity, mortality, frequency, area coverage, community dependence, etc. to inform management activities.
(Potential activities include: Synthesize recreational and commercial fishing effort data from coral reef ecosystems where it exists; determine recreational and commercial effort on key species or functional groups to fill gaps; characterize reef fisheries to understand community dependence and total fishing effort)

Objective 1.4: Predict appropriate levels of extraction for key species or groups by developing and utilizing valid, precise, place-based and realistic ecosystem dynamics models (e.g. ECOPATH).

Objective 1.5: In concert with information from the objectives above, support improvement of statutory, regulatory and management plan frameworks to reach or maintain management targets for priority species or groups.
(Potential activities include: Conduct gap analyses, create timeline-driven plans to address gaps, implement plans, and refine regulatory frameworks)

Objective 1.6: Conduct applied biological, social, and economic research and monitoring to evaluate effectiveness of coral reef ecosystem management actions on key species or groups.
(Potential activities include: Compare fished with un-fished reefs and measure spatial and temporal responses to changes and differences in fishing effort and gear types; increase NOAA and local capacity to collect and

analyze socioeconomic and human dimensions information relevant to assessing the impacts of fishing and management activities on coral reef ecosystems)

Fishing Impacts Goal 2

Support effective implementation and management of marine reserves and marine protected area (MPA) networks, in concert with appropriate land and watershed-use provisions, to reduce the impacts of fishing on coral reef ecosystems.

Marine reserves and other types of protected areas represent a holistic and integrated approach to manage, protect, and conserve coral reef ecosystem resources (NRC 2001). When properly designed and enforced, marine reserves and other MPAs contribute to preserving, restoring and maintaining the ecological functions and services of coral reefs by reducing the impacts of fishing and other extractive, destructive and disruptive activities and uses. MPAs can be used to protect critical and threatened habitats and to facilitate restoration of coral reef ecosystems and their productivity (NRC 2001).

Objective 2.1: Conduct and synthesize research on design characteristics and performance of MPAs and marine reserve networks to protect and restore coral reef ecosystems.

Objective 2.2: Identify, characterize and rank priority areas for protection, including:

- spawning sites, nursery habitats, or other areas critical to particular life-history stages
- biodiversity hotspots
- areas with greatest resilience or potential for restoring resilience
- representative habitats
- areas facing greatest human threats
- areas likely to be most successful in achieving management targets

(Potential activities include: Identify ontogenic linkages of key coral reef species/functional groups among habitats; determine population connectivity of key species/groups for recruitment and population replenishment; develop a reef resilience index to guide siting and management of MPAs)

Objective 2.3: Using outputs of Objective 2.1 and 2.2 and appropriate models, produce gap analysis of existing coral reef ecosystem MPA conservation and management needs, identify MPAs that require increased protections or improved management, and identify areas to be considered for siting of new marine reserves.
(Potential activities include: Develop a management needs and effectiveness index for existing MPA sites.)

Objective 2.4: Work with relevant agencies, offices, and communities to design, implement, and improve the management of regional, ecologically functional networks of marine protected areas or individual marine reserves.

Objective 2.5: Support the creation or improvement of management and enforcement plans for new or existing MPA networks and marine reserves.

Objective 2.6: Conduct biological and socioeconomic research and monitoring necessary to assess the performance of individual marine reserves and MPA networks with respect to protection and restoration of resources, habitats, and ecosystem services.
(Potential activities include: Compare MPA site with non-MPA site or pre-establishment data with post-establishment data to measure impacts on key species or functional groups)

Fishing Impacts Goal 3

Improve public engagement in fisheries management activities and local compliance with and enforcement of management regulations in order to increase coral reef species biomass and restore/maintain coral reef ecosystem habitat.

The success of a management action targeted at reducing the impacts of fishing will be largely dependent on voluntary compliance with or necessary enforcement of regulations, managed areas or best management practices. Management effectiveness will also rely on applicability to a specific geographic area, making local and traditional knowledge a critical component. Increasing community involvement in planning, implementation, and enforcement to reduce impacts of fishing will increase local capacity, buy-in, and communication, all of which are essential to protect key species/functional groups and make marine protected area networks and reserves effective.

Objective 3.1: Support the creation and/or strengthening of stakeholder/citizen groups to participate in fisheries management, planning, and monitoring to improve public input into and buy-in for decision making.
(Potential activities include: Establish a body and/or positions within existing management agencies to liaise with fishers, other affected stakeholder groups, and indigenous communities; support incorporation of locally appropriate mechanisms (including the use of traditional knowledge) for public participation in management action/priority setting initiatives; support implementation of community-based coral reef ecosystem fishery management plans; work with existing or new community-based programs to include the public in resource or socioeconomic monitoring activities; ensure that local needs, concerns, and issues of equity are considered in fisheries regulations)

Objective 3.2: Strengthen local capacity for effective and consistent enforcement of regulations or behaviors that reduce impacts of fishing on coral reef ecosystems.
(Potential activities include: Increase capacity (e.g. personnel, training, equipment, retention systems, outreach) of local agencies; support local community monitoring and patrolling through trainings, enabling legislation or other capacity building; support (as appropriate) traditional methods of enforcement)

Objective 3.3: Identify and support locally-appropriate options to reduce impacts of current extractive livelihoods on coral reef ecosystems.
(Potential activities include: Facilitate regional and/or local discussions on development and implementation of ecotourism opportunities, appropriate aquaculture development, or other non-extractive sources of income; educate users on the importance of reducing or optimizing fishing pressure to achieve long-term sustainability of fishery; understand and balance coral reef fisheries with non-extractive activities)

Objective 3.4: Conduct biological and socioeconomic research and monitoring necessary to assess the effectiveness of compliance and enforcement activities, understand community concerns, and flag roadblocks to implementation.

Fishing Impacts Goal 4

Develop effective education and communication mechanisms to increase public and policy-maker understanding of the importance of management activities that reduce fishing impacts in coral reef ecosystems.

Effective education and outreach mechanisms are critical to communicating basic coral reef ecosystem information and the nuances inherent in research, monitoring and management of these complex ecosystems. Since reef species are so inter-dependent, and since a variety of threats may cause both individual and synergistic effects, management actions may not show an immediate cause/effect impact on the ecosystem. Reducing impacts of fishing on coral reef ecosystems requires improved communication of the goals, values and benefits of management activities leading to broader public support and understanding of their impacts and timelines.

Objective 4.1: Work with national and local departments of education to develop and incorporate coral reef ecosystem and fisheries management information and activities into national or state/territory curricular standards and locally relevant lesson plans.

Objective 4.2: Support the development and implementation of effective strategies or tools that educate policy makers about best management practices to protect key coral reef ecosystem species or functional groups.

Objective 4.3: Develop effective, locally-relevant outreach and communication strategies to increase community support for revised or new regulations of key coral reef ecosystem species/functional groups and expanded use of marine protected areas.
(Potential activities include: Develop multi-leveled approach (resource users, community leaders, policy makers, future generations, etc.); utilize social marketing approaches; develop information and strategies specific to different jurisdiction; help jurisdictions deal with liability issues (school children, public in-water programs, etc)

Objective 4.4: Obtain socioeconomic and human dimension data in jurisdictions to inform education and communication strategies and initiatives and monitor program success.

Objective 4.5: Provide necessary tools for scientists and managers to improve dissemination of research, monitoring, and management results in a way that is easily accessible and understood by policy makers and the public.

Fishing Impacts References

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382

Land-Based Sources of Pollution Working Group
Strategic Goals and Objectives

Coral reefs are in peril in the U.S. and globally, and it is now well accepted that major stressors originate from land-based sources of pollution, including sedimentation and eutrophication. Increasing rates of degradation of coral reefs have occurred throughout the Pacific Ocean, Red Sea, and Caribbean Sea as coastal development continues (Bellwood *et al.* 2004; Pandolfi *et al.* 2003; Richmond *et al.* 2007). Within the U.S., there are numerous locations where coral reefs are highly impacted or threatened by watershed alteration and run-off, and the importance of identifying and reducing these effects has now become crucial, as evidenced by priorities set by the U.S. Coral Reef Task Force. One of the key topics in the April 2004 Report of the U.S. Commission on Ocean Policy includes the need for "an ecosystem and watershed-based management" approach to ocean pollution, and highlights "the astounding decline of coral reef ecosystems" and "an urgent need to address the identified, major factors causing coral declines."

The suite of problems facing coral reefs with regard to land-based pollution is broad and includes sediment, nutrients, and other pollutants from a variety of land-based activities that are transported in surface water runoff, groundwater seepage, and atmospheric fallout into coastal waters. There is compelling evidence that the sources have increased globally as a result of human-induced changes to watersheds (Wilkinson 2008). On the U.S. high islands in the Pacific and Caribbean, significant changes in the drainage basins due to agriculture, deforestation, feral grazing, fires, road building, residence and driveway construction, and urbanization have in turn altered the character and volume of land-based pollution released to adjacent reefs. To underscore this point, the Commission on Ocean Policy reported that "pollution and run-off from coastal areas also deprive reefs of life-sustaining light and oxygen" and many Local Action Strategy (LAS) groups of the U.S. Coral Reef Task Force have identified land-based pollution to reefs as a major area of concern.

Sedimentation, including higher levels of suspended sediment in overlying waters, is commonly acknowledged to be one of the primary causes of reef degradation (e.g. Rogers 1990; Field *et al.* 2008). The combination of suspended sediment and deposited sediment act to limit coral growth, feeding patterns, photosynthesis, recruitment, and more, as shown by numerous studies in a variety of settings (Fabricius 2005). Other impacts of sediment include directly smothering and abrading coral, and triggering increases in macro algae. Although some corals can flourish in turbid water, such reefs are typically less diverse and are more restricted in depth ranges than those in clear water (Fabricius 2005).

Pesticides, pharmaceuticals, heavy metals, and other pollutants, as well as nutrients, add to the deleterious effects of watershed transport onto coral reefs (Richmond 1993). Excess nutrients, including dissolved nitrogen and phosphorus and potassium from sewage and fertilizers, promote the growth of algae that competes with corals for space on the surface of reefs, and in extreme cases can result in eutrophication of reef waters. Run-off may either directly contribute land-derived pathogens or exacerbate the effect of *in situ* pathogens on the reef through nutrient-loading. Studies also indicate in some corals an increased susceptibility to diseases associated with land-derived pathogens (Fabricius and De'ath 2004).

Finally, the local impacts of land-based sources of pollution have the potential to work synergistically with global threats such as climate change, magnifying the effect of both stressors.

It is because of the significant and chronic threats of land-based pollution to coral reefs that NOAA's Coral Reef Conservation Program is establishing a long-term pathway for identifying and controlling land-based sources of pollution. What follows are the guiding Goals and Objectives to establish that pathway.

Land-Based Sources of Pollution Goal 1
Reduce pollutant loading from watersheds to coral reef areas.

Recognizing the profound link between watershed land use activities and the quality of the nearshore marine ecosystems, reducing or eliminating pollutant loads to coral reefs from land based sources is paramount. Because sediment deposition and algal cover are major reef impairments, addressing sediment and nutrient loading from urban/agricultural runoff and wastewater discharges should be a primary focus of watershed management activities. Toxics, pharmaceuticals, pathogens, and debris derived from the land are also pollutants of concern.

Watershed assessment, planning, and restoration efforts to address land-based sources of pollutants should be conducted locally from ridge to reef, preferably in watersheds draining to high quality and/or restorable reef systems. Comprehensive watershed management includes the application of land use planning; land conservation; vegetated buffer protection; environmentally sensitive development techniques; stormwater management (construction and post-construction); wastewater and drinking water management; and stewardship activities with an eye towards coral reef protection and improvement. Supporting our watershed restoration and protection efforts with strategic research and monitoring will be critical to improving our effectiveness in reducing pollutant loads and measuring reef health.

Objective 1.1: Identify and prioritize those coral reefs and associated watersheds, within each jurisdiction, that will contribute the most to coral reef preservation, protection and recovery upon implementing conservation/ management strategies.
(Potential activities include: Establish criteria of physical, ecological, and sociological factors for identification and prioritization of coral reefs and coral habitats impacted and predicted to be impacted by watershed activities, the type and relative degree of impact, and the potential for reversing decline through management activities)

Objective 1.2: Develop (or update) watershed management plans that include comprehensive land and water use strategies and best available science for protecting all priority coral reefs and associated watersheds.
(Potential activities include: Identify any/all previously developed watershed plans (governmental entity or a non-governmental organization) and water quality monitoring data which may add information to the reef-watershed prioritization process or pollution mitigation process; Identify and prioritize the pollutants of concern for each watershed (sediment, nutrient, toxic, and microbial); Identify and prioritize the necessary management actions)

Objective 1.3: Implement watershed management plans and relevant Local Action Strategies (LAS) within priority coral reef and associated watersheds.
(Potential activities include: Develop guidance documents for local jurisdictions that identify and describe the best approaches that have been generated through various watershed management plans and LASs, guidance should also identify gaps in existing plans and provide an example of a "model" plan; Share lessons learned across and among jurisdictions)

Objective 1.4: Promote an applied research agenda to support planning and implementation activities in priority coral reefs and associated watersheds.
(Potential activities include: Establish a dialogue among scientists and managers to promote research questions that will help managers better apply management practices effectively and assess the effectiveness of various types of best management practices)

Objective 1.5: Assess the efficacy of management activities through coordinating necessary baseline and performance monitoring to assess progress and adapt management actions as needed.
(Potential activities include: Establish metrics that are scientifically defensible, management applicable and appropriate, and relevant to program requirements; Conduct baseline and follow-on monitoring to track changes in each coral reef watershed ecosystem to assess the success of implemented actions and adapt management plans and actions as needed)

Land-Based Sources of Pollution Goal 2

Preserve, protect, and restore coastal/watershed systems in priority coral reef areas that maintain the functional landscape using a ridge to reef management approach to enhance coral reef ecosystem resilience and promote recovery.

The health of many U.S. coral reefs is ultimately dependent on the effectiveness of ecosystems in adjacent coastal and upland regions. The natural state of forests, stream valleys, deltas, wetlands, and mangroves is key to maintaining hydrologic functions including base flow and recharge, and to limiting rates of erosion and quantities of transported sediment and other pollutants to adjacent coral reefs. It is therefore essential to maintain or restore coastal and upland ecosystems as a first line of defense limiting land-based pollution of coral reefs.

Objective 2.1: Identify coastal and upland areas for preservation, protection, and restoration based on the coral reefs and associated watershed areas identified in Objective 1.1.
(Potential activities include: Coordinate watershed planning activities with other conservation area planning to identify priority coastal and upland areas for protection)

Objective 2.2: Build partnerships among local, state, federal, and non-governmental entities to identify, leverage, and apply financial and other resources to preserve, protect, and restore coastal and upland ecosystems affecting coral reefs.
(Potential activities include: Identify and partner with existing Federal programs and private organizations that support activities to purchase, preserve, protect, provide easements, and restore coastal habitats)

Land-Based Sources of Pollution Goal 3

Promote natural recovery and restoration of coral reef and associated marine ecosystems that have been adversely impacted by accumulated pollutant loads of sediments, nutrients, and algae.

Coral reefs persist through the dual processes of reproduction and recruitment, which are dependent on water and substratum quality. Accumulated terrigenous sediments retained on reefs by fleshy algae are continuing to prevent coral recovery through re-suspension and interference with fertilization, larval development and settlement in corals. Management actions are needed to increase the flushing of accumulated terrigenous sediments, supporting improved levels of coral population replenishment and coral reef health.

Objective 3.1: Identify those coral reef areas appropriate for restoration activities that enhance habitat quality, based on the coral reefs and associated watersheds identified in Objective 1.1.

(Potential activities include: Compile, in collaboration with local governments and stakeholders and consistent with the criteria developed in Objective 1.1, a list of reef areas for consideration in each jurisdiction)

Objective 3.2: Develop innovative technologies or apply existing technologies that can be applied to coral reef restoration activities.

(Potential activities include: Develop, implement and sustain (satellite) remote sensing based indicators, assessments, and observing capabilities/capacity in support of coral reef management, integrate these efforts with watershed and ocean circulation models; Protect and enhance populations of herbivorous fishes and invertebrates that can control populations of fleshy algae through the use of marine protected areas; Examine natural and mechanical means of controlling algal populations to reduce sediment accumulation and retention on reefs)

Objective 3.3: Promote coral reef ecosystem-based activities that reduce accumulated sediment and fleshy algae to enhance natural flushing and the ability for coral reef ecosystem populations to recover.

(Potential activities include: Control nutrient and sediment input into coastal waters, and in collaboration with the Fishing Impacts Working Group, develop marine protected areas and stock enhancement programs that support the natural maintenance of ecological integrity; Develop criteria that define reef areas, in each jurisdiction, that are negatively impacted by sedimentation and algal overgrowth; Asses reef areas, in each jurisdiction to determine which areas meet the impact criteria; for those impacted reef areas, determine sediment sources or causative factors for algal overgrowth; develop strategies to eliminate sediment sources, remove excess sediment from the reef system, eliminate the causes of algal overgrowth, and/or eliminate excess sediment and macroalgae from the impacted reef areas)

Land-Based Sources of Pollution Goal 4

Build and sustain management capacity at the local level through local, state, regional, and Federal coordination of financial, institutional, and human resources to reduce and prevent the impacts of land-based sources of pollution on coral reef ecosystems.

Land-based sources of pollution occur over multiple governmental and jurisdictional levels. It is therefore necessary to build a framework for coordination, revise regulations to insure

they are protective for coral reefs, and provide funding to implement projects focused on reducing land-based sources of pollution. However in many communities it will first be necessary to build the local, regional and federal capacity to effectively implement and enforce new or existing mechanisms to reduce land-based sources of pollution.

Objective 4.1: Conduct capacity assessment to identify local jurisdiction needs related to managing land-based sources of pollution.
(Potential activities include: Conduct capacity assessments for each jurisdiction)

Objective 4.2: Support and, if needed, help develop intergovernmental mechanisms (appropriately designed for each jurisdiction) that promote effective management and decision-making capabilities at the jurisdiction, community, and watershed level.
(Potential activities include: Identify (by region, jurisdiction, community, and/or watershed) existing intergovernmental relationships and/or organization; assess their effectiveness; develop more targeted partnerships)

Objective 4.3: Ensure that the necessary and consistent regulatory and programmatic framework exists to implement watershed management strategies that protect coral reefs.
(Potential activities include: Support development of erosion control contractor/inspector/operator certification programs; update stormwater design manuals to incorporate Low Impact Development; Support efforts to enhance both regulatory and nonregulatory programs, as well as local enforcement activities, to better address land-based sources of pollution)

Objective 4.4: Leverage existing funding mechanisms and acquire new fiscal and human resources to fill the capacity gaps with local, state, and federal resources.
(Potential activities include: Identify and implement complimentary funding opportunities within each priority coral reef watershed; Coordinate with and support other agency efforts through their specific area of expertise to implement watershed planning efforts)

Objective 4.5: Increase public and political awareness and understanding of the ecological and socioeconomic impacts of land-based pollution on coral reef resources.
(Potential activities include: Support education of elected officials, key constituent groups, and the public regarding matters related to the impacts of land-based sources of pollution on coral reefs)

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Climate Change Working Group
Strategic Goals and Objectives

In 2007, the Intergovernmental Panel on Climate Change (IPCC) noted evidence is now "unequivocal" that the earth's atmosphere and oceans are warming and concluded that these changes are primarily due to human activities. While reducing carbon dioxide (CO_2) and other greenhouse gas emissions is vital to stabilize the climate in the long term, excess emissions already concentrated in the atmosphere will produce significant changes in the global climate now and throughout the next century. These changes are expected to affect corals and coral reef ecosystems globally over the coming century.

Coral reef health worldwide has been on the decline for decades. Warming seas and ocean acidification are already affecting reefs by mass coral "bleaching" events and slowing the formation of coral skeletons (Hoegh-Guldberg *et al.* 2007; De'ath *et al.* 2009). Atmospheric CO_2 has increased by 35% from a preindustrial level of 280 parts per million (ppm) to 385 ppm in 2008, and the rate of increase is accelerating. The recent (1995-2005) average rate of CO_2 increase (1.9 ppm/yr) was 36% faster than the average over 1960-2005 (1.4 ppm/yr, data from CDIAC). This increase is primarily being driven by anthropogenic causes (burning fossil fuels, industry, and deforestation) and has already warmed the ocean and atmosphere. Global ocean temperature has risen by 0.74°C/1.3°F causing more frequent and severe bleaching of corals around the world. Furthermore, an additional global ocean temperature rise of at least 1.0°C/1.8°F, within this century is likely to occur from greenhouse gases already released – even if we stop all further human release of greenhouse gases. 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. This means that coral reef thermal stress and bleaching events are likely to increase in frequency and severity, increasing coral mortality and eliminating important ecosystem services such as habitat for fish and shoreline protection. Already we have lost over 19% of the world's corals (Wilkinson 2008) and up to 80% of coral cover on many Caribbean reefs (Garner *et al.* 2003). The combination of ocean warming and acidification could lead to the loss of most corals and the associated ecosystems that are home to a quarter of all fish and other taxonomic groups in the ocean. 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 negative impacts from land-based sources of pollution and ecologically unsustainable fishing.

The ocean has absorbed roughly 524 billion tons of human attributed CO_2 since the 1700's and currently takes up approximately one-third of the additional CO_2 added every year due to human activities (Sabine *et al.* 2004). The resulting change to ocean chemistry has important consequences to corals and other marine life. Average global ocean pH has dropped 30% since preindustrial times (from around 8.2 to 8.1) (Caldiera and Wickett 2003). There is mounting evidence that such changes may have already made it more difficult for corals to build their calcium carbonate skeletons. Recent work suggests that there may be unanticipated interactions between climate change and ocean acidification stressors that might compound the problems corals face (Anthony *et al.* 2009). Current atmospheric CO_2 already exceeds levels seen during the last 600,000 years, and probably during the last 28 million years. More importantly, the rate of change has occurred much faster than any time in the past, currently in excess of 2 ppm/yr. This is 800 times faster than the rate of increase

over the last 8,000 years (0.0025 ppm/yr). It is highly unlikely that natural systems will be able to adapt fast enough to keep up with this pace of change on their own. Therefore, immediate management policy and management actions are required if tropical ecosystems are to withstand the impacts of climate change and ocean acidification.

The majority of U.S. coral reefs lie within local jurisdictions. For the CRCP to make significant progress towards its goals, it will be necessary to support and improve local management actions. Scientific research and monitoring are critical to successfully implement management actions to conserve coral reefs. Federal-local partnerships must be strengthened, particularly in the areas of communication, collaboration, and the implementing of joint management actions. Sound science must drive effective policy-making. Federal support is needed not only to help finance local efforts, but also to encourage and support the translation of scientific information into forms useable by managers and decision-makers. Federal-local partnership is required to successfully address the local and international impacts of climate change.

Three sets of actions are needed to protect coral reefs from greenhouse gas-related stress. First, we must address the rise in greenhouse gases. This will require reducing emissions, followed by reducing accumulated greenhouse gases to levels reefs can tolerate. At the time that these Goals and Objectives were written, the EPA had just submitted a finding that greenhouse gases are pollutants that endanger the public's health and welfare and should be regulated under the Clean Air Act. President Obama and Congressional leadership have indicated their desire for America to confront the threat of climate change. While regulating emissions falls outside of NOAA's mandate, NOAA does have a critical role in monitoring climate change and ocean acidification, projecting their associated impacts, and assessing the danger of these impacts and ways to address them that supports local, national, and international policy. With at least 0.5°C warming expected by 2100 from CO_2 already in the atmosphere, it is clear that we must act locally to help coral reefs survive this century. The second set of actions is to increase the resilience of coral reef ecosystems to climate change by managing local stressors including land-based sources of pollution and ecologically unsustainable fishing. Through management of local or secondary stressors we can increase the ability of corals and coral reefs to resist and recover from events such as coral bleaching and ocean acidification. The third set of actions is to find ways to identify and reduce the local impacts of climate change and ocean acidification on coral reefs and to help corals and coral reefs increase their tolerance. These latter two sets of actions will help keep coral reef ecosystems intact until greenhouse gas levels are stabilized and reduced to sustainable levels and do fall within NOAA's mandate.

To address the problems of anthropogenic climate change and ocean acidification the NOAA Coral Reef Conservation Program has identified four 20-year Goals that need to be addressed simultaneously to help coral reefs cope with climate change. These are:

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

These goals are presented in a logical order but must be addressed simultaneously. This document provides the Goals and the associated objectives to address in the first 5 years.

Following each objective is a set of potential activities that help to identify how these objectives may be met. These are only examples and actual activities will be developed in CRCP's implementation planning to follow.

Climate Change Goal 1: Manage for Resilience

Increase coral reef resilience to climate change and ocean acidification through effective management strategies.

The decline and loss of most coral reefs is due to a combination of the global pressures of climate change and ocean acidification coupled with regional and local stressors and cumulative impacts from land-based sources of pollution, ecologically unsustainable fishing, and habitat destruction associated with coastal development. All of these 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, the ability for coral reefs to resist or be resilient to the impacts of climate change depends on resilience-enhancing, local management actions. The concept of resilience underpins effective ecosystem-based management (Levin and Lubchenco 2008). While human society can adapt to climate change through technology, natural ecosystems cannot. We need to create the space for adaptation and adjustment to take place in coral reef ecosystems. Managers want and need to know what they can do now to protect coral reefs against climate change impacts, while they continue to target non-climate stressors. This goal recognizes the importance of providing managers with a set of tools to do everything possible to restore and maintain the resilience of coral reef ecosystems.

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 strengthened and applied more effectively. However, we must also acknowledge that the current lack of capacity constrains local coral reef management success and must be addressed to enable timely implementation of strengthened existing and new management strategies to increase coral reef resilience. Therefore, strongly linking coral reef conservation to human welfare through effective communication will be required to secure stakeholder and legislative support for strengthened and new management actions needed to save coral reefs.

The goal *Manage for Resilience* is organized around 5 objectives which outline a comprehensive approach towards maximizing the resilience of coral reefs in US jurisdictions. The objectives under this goal will support coral reef management success by building management capacity and strengthening governance and public support for immediate action to effectively reduce stressors known to weaken reef resilience; implementing and evaluating existing and emerging tools to forecast climate change impacts and protect reefs by conferring resilience to impacts; developing place-based crisis response plans; and enabling 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.

Objective 1.1: Increase coral reef managers' capacity to reduce the impacts of climate change and ocean acidification recognizing that reduction of non-climate change stressors is required to reduce vulnerability to climate change impacts.
(Potential activities include: Increase manager's understanding of the climate change threat; working with managers and scientists to identify region-specific resilience bottle-necks; identify and support implementation of strategic management activities that increase resilience; support enhanced/increased legislative authority to implement strengthened existing, and new management strategies)

Objective 1.2: Develop and implement communication plans that provide relevant and up-to-date information on climate change and ocean acidification to meet specific needs of stakeholders (e.g., policy makers, fishers, tourism industry, and the general public).
(Potential activities include: Develop strategic, long-term communication plans that address broader communication purposes at local, national, and international scales - to include impacts, management response and results, convey limitations, and the role of citizens in responding to climate change; develop outreach materials and delivery mechanisms that 'make the case' for climate change that target key audiences; develop and publicize US & international case studies on impacts of climate change and ocean acidification to encourage greenhouse gas reduction)

Objective 1.3: Develop and implement climate related crisis response plans in all US coral reef jurisdictions (e.g., bleaching events, disease outbreaks, tropical storm impacts, and major rainfall events).
(Potential activities include: Improve early warning systems for acute disturbances; 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)

Objective 1.4: Develop, implement, and evaluate management and regulatory actions to improve resilience to climate change and ocean acidification (need to do this at broader ecosystem-based scales if we expect to see measurable results).
(Potential activities include: 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; and protect these from local non-climate change stressors through MPA designation; incorporate resilience-based strategies into management activities; use predictive tools to estimate value of management actions to increase resilience; evaluate the effectiveness of those management actions; enhance the ability of agencies to encourage compliance and enforce regulations)

Objective 1.5: Translate best available science into applied management strategies to produce new and innovative tools for managers responding to climate change impacts.
(Potential activities include: Define "intact, sustainable coral reef ecosystem"; encourage dialogue between managers and scientists to identify priority science; work with scientists to identify the management implications of their research findings; synthesize relevant scientific findings for management application; develop specific management tools and processes based on relevant science and management successes; develop a simple, scientifically supported, matrix to enable managers to determine if local reefs are over-harvested, overused, or otherwise unsustainable; develop methods to *encourage management action on threats identified by relevant scientifically robust research, and to ensure adequate compliance and enforcement)*

<u>Climate Change Goal 2</u>: Address Risks and Vulnerability

Identify, understand, and communicate risks and vulnerability of US coral reef ecosystems (and dependant human communities) to climate change and ocean acidification to enhance preservation of ecosystems services.

Understanding the current state of coral reef health and monitoring the impacts and response of reefs to global climate change and ocean acidification are essential steps for assessing and demonstrating the vulnerability of coral reef ecosystems. Objectives within the *Address Risks and Vulnerability* Goal focus on clearly understanding and describing the changes occurring on coral reef ecosystems in the face of our changing climate, the effects on and response of human communities dependent on coral reef resources, and assessing both the environmental and socioeconomic risks to coral reef communities. 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. These activities will also provide the documentation necessary to empower managers to act on the impacts of climate change and ocean acidification.

Assessing the vulnerability of coral reefs to climate change and ocean acidification requires characterization of changes in the physical and chemical state of the environment and the response of coral reefs to these changes from organism to ecosystem scales. Linking ecosystem response to climate and synergistic stressors depends upon developing coral reef health indicators of the stresses affecting coral reefs. It is essential to discern impacts and indicators resulting both from local disturbances (e.g. ecologically unsustainable fishing, land-based pollutants, etc.) and global climate change (including temperature and seawater chemistry changes), and the complex interplay among these multiple stresses necessary to effectively assess the risk and vulnerability of individual reef ecosystems. Inventory and analysis of current coral monitoring and research programs should be conducted to identify gaps, leverage existing assets, and where necessary guide the enhancement of these efforts to identify and track climate relevant thresholds (e.g., pCO_2, temperature, and pH). Sustained monitoring of coral community changes to acute and chronic climate change disturbances and response to management, adaptation, and intervention actions aids in; 1) quantifying long-term trends and correlations among climate change impacts and reef response, 2) assessing the ability for biological adaptation of coral reef organisms to climate change effects, and 3) evaluating effectiveness of intervention and adaptation strategies. In addition, current socioeconomic monitoring, analysis, and modeling efforts need to be expanded to include climate change risks and costs to coral reef resources and dependent human communities. Finally, good stewardship of coral reef ecosystems demands effective communication of risks and monitoring of human responses to climate induced resource changes.

<u>Objective 2.1</u>: Characterize physical and chemical changes in coral reef environments relative to climate change and ocean acidification. (requires expansion of question-based monitoring of coral reef ecosystems to fill gaps in our current observations on climate change and its impacts on coral reef ecosystems)

(<u>Potential activities include</u>: Establish physical/chemical baselines and thresholds including spatial and temporal variability at priority sites (define criteria and identify priority sites); perform gap analysis of existing physical/chemical monitoring programs within the context of climate change and adjust/expand as necessary; develop new tools needed to better assess environmental changes and their potential impacts)

Objective 2.2: Conduct ongoing biological and ecological assessments of coral community changes relative to climate change and ocean acidification impacts to ecosystem services.
(Potential activities include: Establish biological/ecological baselines including spatial and temporal variability at key sites; perform gap analysis of existing biological monitoring programs within the context of climate change and adjust/expand as necessary; identify the current state of knowledge of threshold responses and relevant relationships between coral reef organisms and climate change stressors; develop a set of coral reef health indicators (of symptoms) related to climate change and use to measure response to changes in physical and chemical status over time)

Objective 2.3: Develop and conduct ongoing monitoring of socioeconomic effects of climate change impacts on coral reef ecosystems.
(Potential activities include: Identify vulnerable human communities in order to communicate levels of risk; establish socioeconomic baselines at key sites against which to measure future change; coordinate with existing socioeconomic monitoring programs to perform gap analysis and establish socioeconomic indicators (behavior, resilience, adaptation and maladaptation) of human responses to coral climate impacts on coral reef; identify socioeconomic impacts or costs associated with climate change impacts on coastal communities)

Objective 2.4: Promote conservation of coral reef ecosystems through identification of potential Areas Resilient to Climate Change (ARCCs) for actions to avoid and minimize climate change impacts. (spreading risk)
(Potential activities include: Define criteria necessary to identify vulnerability and potential resilience to climate change in coral reef ecosystems; assess all US Coral Reef jurisdictions to identify locations for establishing ARCCs using input from local scientific and management communities; provide a suite of management actions that can be taken in these ARCCs)

Objective 2.5: Provide and communicate regular national comprehensive risk assessment of the threat of climate change and ocean acidification to reefs and dependent human communities to managers (e.g., *State of Coral Reef Ecosystems of the US*, *Status of Coral Reefs of the World*, *Global Socioeconomic Conditions Report*, and *IPCC Assessment Reports*, etc.).
(Potential activities include: Greater representation of risk to coral reefs in IPCC Working Group II Assessments; use risk assessments to communicate to the public and policy makers the need to mitigate climate change and reduce impacts; 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)

Climate Change Goal 3: Provide Forecasts & Projections
Enhance strategic management of coral reef ecosystems through improved and applied forecasts and projections of climate change and ocean acidification impacts.

For the past few decades the use of climate models has been the best and most useful way of understanding future climate change and what these changes may mean to human and other natural systems. A large climate modeling community has grown out of this effort, and as a result, has produced an impressive amount of data and information on the climate system. Despite the impacts of climate change to coral reefs and coral ecosystems, the coral community has not effectively integrated or applied this information. The lack of integration is likely a result of vastly differing disciplines and a lack of interdisciplinary groups working to bridge this gap. Efforts like the past Intergovernmental Panel on Climate Change

assessments help, but most of these have provided information at the continental, sub-continental, and ocean basin scales. The reality is that these climate trends and their impacts will vary substantially at the regional and local level.

Information from the climate modeling community continues to improve, however, and is increasingly applicable to questions asked at finer scales. For this information to be helpful to managers and decision-makers, integrated teams need to effectively interpret and apply the data to questions of local importance. The coral community has not been effectively engaged in this effort, and as a result, is ill equipped to understand the potential impacts of climate change to corals and coral reef ecosystems and the human communities that depend on them. As degradation of coral ecosystems continues to persist from climate change, it is becoming increasingly important to improve the connection between the climate modeling community, and the large amount of data that it has already produced, and coral reef scientists and managers. To improve this connection, a more focused attempt must be made at collaboration and translation of climate forecasts and projections. Collaboration will be important to ensure the information that is being produced is applicable to coral ecosystems and is at spatial and temporal scales that are meaningful for managers and policymakers. Translation will be necessary as managers and policy makers have a variety of needs and will need to employ this information for multiple circumstances. This will require a secondary effort to develop tools and products from the climate forecasts and projections that are useful and can improve management and policy decisions regarding the health and future sustainability of corals and coral reef ecosystems.

The purpose of this goal is to improve integration of state-of-the-art climate modeling forecasts and projections into reef management decisions. We aim to do this through enhanced collaboration with the large and robust climate modeling community, focused on using forecasts and projections to anticipate future stresses on corals and coral reef systems and their dependent communities. Enhanced, high-resolution climate information will ultimately be translated to useable products from which coral managers and policymakers can plan and make strategic decisions. We expect that by anticipating stresses on reef systems, managers can make more sound management decisions to minimize negative impacts on both reefs and local communities. We also hope that by providing a compelling rationale for regional ocean studies in tropical reef environments, this goal will accelerate the pace of research (i.e. the development of suitable regional model projections) in this field.

Objective 3.1: Collaborate with climate change modeling groups to assess physical and chemical forecasts and projections at spatial and temporal scales appropriate to inform management decisions.
(Potential activities include: Improve capabilities for short term forecast of climate change stress to aid in management decision making; establish projections to compare with future observations; perform gap analysis on current observations; interact with the modeling community to ensure we receive the correct information; develop scenarios projecting future impacts of climate change and ocean acidification)

Objective 3.2: Increase understanding of the response of corals and associated reef organisms to physical and chemical changes (SST, CO_2) associated with climate change, ocean acidification, and interactions with other stressors. (organism response)
(Potential activities include: Conduct experiments on thermal and chemical effects on representative organisms at multiple life stages and multiple responses (disease, bleaching, calcification, reproduction, etc); conduct

experiments on how thermal and chemical effects interact with other stressors and influence responses such as bleaching and disease; identify partnerships with other agencies and groups to accomplish the necessary research)

Objective 3.3: Increase understanding of ecosystem level consequences of climate change ocean acidification. (project changes in functional diversity of reef e.g., the cascading effects to ecosystems if they lose x number of species or x percent of coral cover)
(Potential activities include: Model species interactions; conduct mesocosm experiments to look at community interactions; conduct large scale field and natural experiments)

Objective 3.4: Predict impacts on reef dependent human communities from the effects of climate change and ocean acidification on coral reef ecosystems.
(Potential activities include: Work with social science portion of CRCP to better understand and communicate human dependence on coral reefs; determine the economic value of predicted coral reef loss due to climate change and ocean acidification; project future vulnerable of reef dependant human communities in order to communicate levels of risk)

Objective 3.5: Translate forecasts and projections into relevant and useable products for coral reef management and decision making.
(Potential activities include: Establish dialogue between science and management to identify key needs in forecasting climate change impacts (products); improve forecasts and projections in both accuracy and utility; understand and communicate the implications climate change and ocean acidification for management of related ecosystems)

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

Attempts to maximize the resilience of coral reefs to climate change and ocean acidification are challenged by the fact that reef managers have little direct control over the relevant environmental stressors (rising temperatures and CO_2 levels). In addition, committed physical and chemical changes on reefs resulting from greenhouse gases already in the atmosphere establish baseline future projections that are already likely to result in significant harmful impacts on reefs. Consequently, it is likely that reefs will suffer future climate change and ocean acidification impacts even if they are well managed in all other respects.

The primary purpose of this goal is to support direct efforts to maximize survivorship on reefs affected by climate change and ocean acidification. Although necessarily limited in their scope, intervention attempts have value when targeted at reefs which contain particularly valuable or threatened species or populations, or which a have a high relative abundance of large reproductive colonies. Similarly, efforts to protect a network of small sites may be worthwhile if they help a larger reef area recover, or when the reef area in question has historically remained resilient to all other stressors.

Underlying this goal is the recognition that 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 their survivorship, if other approaches to prevent impacts fail. This goal begins the process of how best to reduce impacts in preparation for likely future need, and helps establish potential tipping points when such activities may be merited.

Objective 4.1: Facilitate the development and testing of intervention measures to reduce stressors or impacts from climate change and ocean acidification on coral reefs in field settings.
(Potential activities include: Support the development and evaluation of intervention measures designed to reduce climate change and ocean acidification impacts, including but are not limited to, in situ *environmental control; enhancing evolutionary adaptation by propagating or promoting stress tolerant genotypes; and enhancing coral recruitment and succession; use predictive tools to evaluate the likely success of management intervention measures; produce progress report on development)*

Objective 4.2: Work with managers to provide objective tools to evaluate the effectiveness, applicability, and feasibility of intervention strategies. (intervention toolkit)
(Potential activities include: Identify appropriate sites for larger scale field testing and implementation; evaluate potential negative consequences of intervention measures; develop and periodically update list of potential strategies, evaluate relative feasibility of implementation; produce progress report on testing implementation and results)

Objective 4.3: Support implementation of promising intervention strategies to reduce the impact of climate change and ocean acidification on coral reefs.
(Potential activities include: Build capacity and provide training for implementation activities; promote implementation through targeted communication; establish or improve facilities to implement intervention strategies; evaluate the effectiveness of management actions to conserve and protect coral reef ecosystems)

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