INCORPORATING CLIMATE AND OCEAN CHANGE INTO AN

ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT (EAFM) PLAN

CORAL TRIANGLE INITIATIVE
ON CORAL REEFS, FISHERIES AND FOOD SECURITY

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Incorporating Climate and Ocean Change Into an Ecosystem Approach to Fisheries Management (EAFM) Plan

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COVER PHOTO: Fishing boats, Malaysia. © CTSP / Tory Read

TABLE OF CONTENTS

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

CCA – Climate change adaptation

ICZM – Integrated coastal zone management

IPCC – Inter-governmental panel for climate change

LEAP – Local early action plan

MPA – Marine protected areas

MSP – Marine spatial planning

NGO – Non-governmental organization

SPC – Secretariat of the Pacific Community

SRES – Special Report on Emission Scenarios

VA – Vulnerability assessment

WCPFC – Western and Central Pacific Fisheries Commission

GLOSSARY

ADAPTATION – Adjustment in natural or human systems in response to actual or expected climate and/or ocean change or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation include: anticipatory, autonomous, and planned adaptation (IPCC 2007).

ADAPTATION OPTIONS – The range of actions that can be taken to reduce vulnerability of a target resource to climate and/or ocean change. For a social resource target such as housing, adaptation options may include moving housing, developing new building standards, or retrofitting existing housing to withstand a climate threat. For natural resources targets, such as coral reefs, adaptation options may include strengthening or expanding existing management efforts such as improving enforcement of existing marine protected area or expanding protection to a network of marine protected areas.

ADAPTIVE CAPACITY – The ability of a system to adjust to *climate change* (including *climate variability* and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2007).

ADAPTIVE MANAGEMENT – A systematic process for continually improving management policies and practices toward achieving articulated goals and objectives by learning from the outcomes of previously employed policies and practices. The basic steps of adaptive management are to conceptualize; plan actions and monitoring; implement actions and monitoring; analyze, use, and adapt; and capture and share learning. Active adaptive management is where management options are used as a deliberate experiment for the purpose of learning (Millennium Ecosystem Assessment 2006).

BENCHMARK – A standard against which something can be measured or judged. Used as a planning tool to catalyze and guide local implementation of a particular process. Benchmarks can help to identify the level and status of a group's efforts on a particular project.

BIODIVERSITY – The variation of life at all levels, ranging from genes to ecosystems. It is more than a count of species and can be characterized by extinctions, reductions, or increases of some species; invasions and hybridizations; degradation of habitats; and changes in ecosystem processes.

CLIMATE – Weather averaged over a long period of time (typically over 30 years or more). Climate is what you expect; weather is what you get (IPCC 2007).

CLIMATE CHANGE – A change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC 2001).

CLIMATE CHANGE ADAPTATION (CCA) –Actions taken to help society, communities, and ecosystems moderate, cope with, or take advantage of actual or expected changes in climate conditions. Adaptation can reduce vulnerability, both in the short and long term (IPCC 2001).

CLIMATE STORY – The summary of past, present, and potential future climate conditions and their potential impacts on target resources of importance to a community or society. The climate story is developed based on both community-based and scientific observations of climate change and potential impacts on target resources and the provision of ecosystem services.

CLIMATE VARIABILITY – The climatic variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Examples of climate variability include inter-annual El Niño and La Niña events, which occur every two to seven years and influence weather patterns over vast regions of the globe (IPCC 2001).

COASTAL AND MARINE SPATIAL PLANNING (CMSP) – A public process of analyzing and allocating the spatial and temporal distribution of human activities in coastal and marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process. Sometimes used interchangeably with marine spatial planning (MSP) (Ehler and Douvere 2009).

CO-MANAGEMENT – A partnership arrangement between key stakeholders (e.g. communities of local resource users, such as fishers, tour operators, coastal developers, etc.) and government to share the responsibility and authority for the management of fisheries and coastal resources, with various degrees of power sharing.

COMMUNITY BASED MANAGEMENT (CBM) – Management planning and implementation carried out by the people and stakeholders in a community.

CONNECTIVITY – The demographic linking of local populations through dispersal of pelagic larvae and movement of juveniles or adults. There are different types of connectivity including connectivity among populations in the same habitat in different locations; connectivity among marine habitats (e.g. where species use different habitats at different stages in their life history); and connectivity between the land and the sea (Jones et al 2009; Green et al. 2013).

CORAL TRIANGLE INITIATIVE ON CORAL REEFS, FISHERIES, AND FOOD SECURITY (CTI-CFF) – A partnership of six countries (Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste) working together to sustain extraordinary marine and coastal resources by addressing crucial issues such as food security, climate change, and marine biodiversity (CTI-CFF 2009).

CTI-CFF REGIONAL PLAN OF ACTION (RPOA) – A 10-year, living, and non-legally-binding document to conserve and sustainably manage coastal and marine resources within the Coral Triangle region. The RPOA takes into consideration laws and policies of each country in the Coral Triangle (Indonesia, Malaysia, Philippines, Timor-Leste, Papua New Guinea, and the Solomon Islands) (CTI-CFF 2009).

ECOSYSTEM – A relatively self-contained system that contains plants, animals (including humans), microorganisms, and non-living components of the environment, as well as the interactions between them (SPC 2010).

ECOSYSTEM APPROACH (EA) – A strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way. Often used interchangeably with ecosystem-based management (EBM) (CBD 2000).

ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT (EAFM) – An approach to fisheries management and development that strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. An EAFM is a practical way to implement sustainable development for the management of fisheries by finding a balance between ecological and human well-being through good governance. The purpose of EAFM is to plan, develop, and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems (Garcia et al., 2003; Food and Agriculture Organisation 2003, 2011).

ECOSYSTEM APPROACH TO FISHERIES MANAGEMENT PLAN (EAFM PLAN) – The output of a planning framework that outlines the integrated set of management arrangements for a fishery to generate more acceptable, sustainable, and beneficial community outcomes.

ECOSYSTEM GOODS AND SERVICES – The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services, such as flood and disease control; cultural services, such as spiritual and cultural benefits; and supporting services, such as nutrient cycling or waste degradation, that maintain the conditions for life on Earth.

ECOSYSTEM-BASED FISHERIES MANAGEMENT (EBFM) – Considered a component of ecosystem-based management, focused on the fisheries sector, EBFM considers both the impacts of the environment on fisheries health and productivity and the impacts that fishing has on all aspects of the marine ecosystem. Often used interchangeably with an ecosystem approach to fisheries management (EAFM).

ECOSYSTEM-BASED MANAGEMENT (EBM) – A management framework that integrates biological, social, and economic factors into a comprehensive strategy aimed at protecting and enhancing the sustainability, diversity, and productivity of natural resources. EBM "emphasizes the protection of ecosystem structure, functioning, and key processes; is place-based in focusing on a specific ecosystem and the range of activities affecting it; explicitly accounts for the interconnectedness among systems, such as between air, land, and sea; and integrates ecological, social, economic, and institutional perspectives, recognizing their strong interdependencies." Sometimes used interchangeably with ecosystem approach (EA) (McLeod et al., 2005).

EXPOSURE – The extent to which a region, resource, or community experiences changes in climate. For example, a house on the shoreline will be more exposed to storm surges than a house further inland at a higher elevation (IPCC 2007).

FISHERY MANAGEMENT UNIT (FMU) – The area of the ecosystem and fisheries that are the focus for management under an ecosystem approach to fisheries management. The fisheries can be any particular types of fishing—e.g. trawl fishery—and/or a particular resource fishery—e.g. shrimp fishery.

FOOD SECURITY – The availability of consistent and sufficient quantities of food, access to appropriate and sufficient foods, and consumption or appropriate use of basic nutrition and food preparation.

FOOD WEB – A system of interlocking and interdependent food chains.

FRAMEWORK – A basic structure underlying a system or context. A framework can serve as a basis of policies and approaches widely accepted enough to serve as a guide in the design and operation of a system. See ecosystem-based management for an example.

FUNCTIONAL GROUP – A collection of species that performs a similar function in ecosystem processes irrespective of their taxonomic grouping (Steneck and Dethier 1994), such as predators, grazers, bioeroders, primary producers, and habitat builders (e.g., Done et al. 1996).

GOVERNANCE OR GOVERNANCE SYSTEM – The way formal and informal rules are set and implemented. It includes the planning and implementation mechanisms, processes, and institutions through which citizens and governing groups (institutions and arrangements) voice their interests, mediate differences, exercise their legal rights, and meet their obligations.

HABITAT – The environment in which the fish and other living marine resources live, including everything that surrounds and affects their life—e.g., water quality, bottom, vegetation, associated species (including food supplies).

HAZARD – A dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury, or other health impacts; property damage; loss of livelihoods and services; social and economic disruption; or environmental damage. Hazards can include latent conditions that may represent future threats and can have different origins. Each hazard is characterized by its location, intensity, and probability (World Meteorological Organization).

HAZARD RISK REDUCTION – Hazard risk reduction is the suite of actions that can be taken to minimize vulnerabilities and disaster risks throughout a society. Actions to reduce risk from natural and man-made hazards include those to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development (World Meteorological Organization).

INDICATOR – A variable, pointer, or index that measures the current condition of a selected component of the ecosystem. The position and trend of the indicator in relation to a benchmark indicates the present status of the component. Indicators provide a bridge between objectives and action.

INTEGRATED COASTAL MANAGEMENT (ICM) – An ecosystem approach to managing a coastal area. A continuous mechanism that involves a systematic process for managing competing issues in marine and coastal areas, including diverse and multiple uses of natural resources. ICM puts into practice effective governance, active partnerships, practical coordinating strategies, sustainable financial resources, and strengthened technical institutional capacities. Under ICM, decisions are taken for the sustainable use, development, and protection of coastal and marine areas and resources.

INTEGRATED MANAGEMENT PLAN – The integrated management plan is both a process and a document. Its primary goal is to provide a planning framework to achieve healthy ecosystems and sustainable use of fisheries resources and the process by which a given area will be managed for a period of time.

LIVELIHOOD – "How we make our living, the things we use, and the choices we make to ensure that our lives run as we like." A sustainable livelihood, then, is a livelihood that "can continue into the future despite any changes and disasters and without losing that which makes the livelihood possible. This may include food production or being prepared for natural disasters. It is important to remember that income generation may be just one part of a livelihood" (Govan 2011).

LOCAL EARLY ACTION PLAN (LEAP) – A summary of the outputs of the four steps described in this guide. It includes a profile of the community, a climate story, assessment of vulnerability of target resources, and priority adaptation actions that a community wants to take to reduce vulnerability to climate and ocean change. The LEAP can serve as a stand-alone document that can be used to support budget requests, or parts of it can be integrated into existing plans (US CTI Support Program 2013).

LOCALLY MANAGED AREA – Any area of coastline and marine waters that is managed by the local community in collaboration with government or non-governmental organizations. This definition was developed to be inclusive of other commonly used terms for this type of locally based management including: Locally Marine Managed Areas (LMMAs); Territorial Use Rights in Fisheries (TURFs); Community-Based Coastal Resource Management (CBCRM); and Community-Based Management (CBM). LMAs can be a tool for any or all of the following: fisheries management, biodiversity conservation, threatened species management, eco-tourism development, and climate change adaptation (Gombos et al. 2013).

MALADAPTATION – An action implemented to reduce vulnerability to climate and/or ocean change that impacts adversely on or increases the vulnerability of other systems, sectors, or social groups (Barnett and O'Neill 2010).

MANAGEMENT GOAL – A broad statement of a desired outcome. Goals are usually not quantifiable and may not have established time frames for achievement.

MANAGEMENT MEASURES – Specific controls applied to achieve the management objective, including gear regulations, areas and time closures (see MPA), and input and output controls on fishing effort.

MANAGEMENT OBJECTIVE – A description of a set of activities that, once completed, will achieve the desired outcome. Objectives can be quantified and measured and, where possible, have established time frames for achievement.

MANAGEMENT PLAN – An explicit set of rules governing how to apply the principles and framework of natural resource management in a given area. This plan may be adapted to changes in the natural and social environment or upon the basis of new information about how a system functions. It may or may not have a legal basis for implementation.

MARINE PROTECTED AREA (MPA) – A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values. MPAs include a wide variety of governance types (including community based areas), and include but are not limited to marine reserves where no extraction is permitted (Dudley 2008; IUCN-WCPA 2008).

MARINE SPATIAL PLANNING (MSP) – See coastal and marine spatial planning

NON-CLIMATE THREATS – Non-climate threats include natural hazards and local man-made threats. Non-climate threats make existing resources more sensitive to climate impacts. Target resources may be exposed to natural hazards such as tsunamis and earthquakes. Upland deforestation can cause sedimentation of nearshore waters, degrading coral reef habitats and making them more sensitive to climate impacts from, for example, increased sea surface temperature and ocean acidification.

OCEAN ACIDIFICATION (OA) – Ocean acidification occurs when CO_2 from the atmosphere is absorbed into the ocean, reacting with water to create carbonic acid, decreasing both ocean pH and the concentration of the carbonate ion, which is essential for calcification by calcifying marine organisms such as corals (Kleypas et al. 2006).

OCEAN CHANGE – A change in the state of ocean conditions that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties (e.g. temperature, salinity, currents, pH, etc.), and that persists for an extended period, typically decades or longer. Ocean changes of particular concern include ocean acidification, ocean warming, and ocean de-oxygenation.

OPERATIONAL OBJECTIVE – A short-term objective achievable through management intervention.

OUTCOME – The change in status, attitude, or behavior that results from a set of management activities. An outcome should be able to be tracked through measurement and/or observation over time.

PRECAUTIONARY APPROACH – Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (UNCED 1992).

PRECAUTIONARY PRINCIPLE – Preparing for unknown changes and protecting resources is the best approach for long-term community resilience to keep resources healthy in the long-term. With or without climate and/or ocean change impacts, these are things that will help our community be happier and healthier over time.

PROMOTING AGENCY – The government agency that takes the lead in promoting a new concept, such as EAFM.

RECRUITMENT – The addition of a new cohort to a population, or the new cohort that was added. The magnitude of recruitment depends on the time and life history stage at which it is recorded (Mora and Sale 2002).

RISK – A function of probability and consequence. Risk assessment is the process intended to calculate or estimate the risk to an object or system. Risk assessment includes identifying the severity of a hazard (its impact) and likelihood of it happening.

SENSITIVITY – The degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (IPCC 2007).

STAKEHOLDER – Any individual, group, or organization who has an interest in (or a "stake"), or who can affect or is affected, positively or negatively, by a process or management decision.

SUB-NATIONAL – A geographic or governance area that is smaller than the national level. Sub-national includes all designations of vertical governance structure between the community level and the national level. Examples include province or multi-province; local government unit (or regency) or multiple local governments working together; and other appropriate designations.

SUSTAINABLE DEVELOPMENT – Development (improvement in human well-being) that meets the needs of the present without compromising the ability of future generations to meet their own needs.

SUSTAINABLE USE – The harvesting of natural resources that does not lead to long-term decline of the resource and biodiversity, thereby maintaining its potential to meets the needs of the present without compromising the ability of future generations to meet their own needs.

US CTI SUPPORT PROGRAM IMPLEMENTATION PARTNERS – Lead national agencies for MPAs, fisheries, and environment, Coral Triangle Support Partnership (CTSP) consortium members and other NGOs, key academic and technical persons involved in setting policy for MPAs, fisheries, and climate change, and CTSP field staff who lead projects in each country supported by the US-CTI.

US CTI SUPPORT PROGRAM INTEGRATION SITES – Geographic areas where the integration of MPA, fisheries, and climate change adaptation strategies are being planned and implemented under US Government funding and in support of Coral Triangle Initiative goals and objectives.

US CTI SUPPORT PROGRAM PRIORITY GEOGRAPHIES – Broad geographies within which are the project sites, where CTSP is providing technical and financial support for field conservation.

VULNERABILITY – The degree to which a human or natural system is susceptible to, and unable to cope with, adverse effects of climate and/or ocean 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 (IPCC 2001).

VULNERABILITY ASSESSMENT (VA) – An evaluation of the exposure, sensitivity, and adaptive capacity of a target resource to climate and/or ocean change threats. It serves as a primary input to adaptation planning.

VULNERABLE SPECIES – A species considered to be facing a high risk of extinction in the wild (IUCN 2010).

WEATHER – Atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future. You can observe the weather by looking outside to see if it is raining, windy, sunny, or cloudy. You can tell how hot or cold it is by looking at a thermometer.

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SECTION 1

INTRODUCTION

1.1 WHAT IS THE PURPOSE OF THIS CLIMATE AND OCEAN CHANGE ADDENDUM?

The countries in the Coral Triangle (Indonesia, Malaysia, Papua New Guinea, Philippines, Solomon Islands, and Timor-Leste) are committed to applying an Ecosystem Approaches to Fisheries Management (EAFM) through the Coral Triangle Initiative's (CTI) Regional Plan of Action for coral reefs, fisheries, and food security. There is, however, uncertainty over what needs to be done on local, national, and regional levels to develop an EAFM plan and transition towards this more holistic approach to fisheries management. The principals of an EAFM, and a suggested planning framework for implementing an EAFM, are outlined in the attached *Coral Triangle Regional Ecosystem Approach to Fisheries Management Guidelines*.

The purpose of this addendum is to highlight how the potential impacts of climate and ocean change can be integrated into the EAFM planning process. Ultimately, dealing with the effects of climate and ocean change may become an implicit part of future EAFM plans; however, we have made a distinction here as an EAFM is a relatively new management paradigm for countries in the Coral Triangle (and elsewhere around the world). Moreover, climate and ocean change are relatively new challenges to be addressed in fisheries management. Therefore, the purpose of this addendum is to highlight and draw special attention to addi-

tional activities which, if included in the EAFM planning process, specifically incorporate climate and ocean change concerns into EAFM plan development. These additional activities can be useful in identifying whether the impacts of climate and ocean change are priority issues for a particular Fisheries Management Unit or geographic area. If so, climate adaptation and mitigation actions can then be included in the EAFM plan.

The guidance outlined here is specifically intended to be used alongside the *Coral Triangle Regional Ecosystem Approach to Fisheries Management (EAFM) Guidelines*. Together, the *Guidelines* on the EAFM planning process and on climate and ocean change can be used to understand and plan for the non-climate, climate, and ocean change threats to near-shore fisheries and coastal habitats. The planning process is intended to be applied within a defined Fisheries Management Unit, in which there are clear governance structures and decision-making processes.

1.2 WHO SHOULD USE THE GUIDELINES?

These guidelines are intended to be used by the key agencies, stakeholders, and/or non-governmental organizations (NGOs) central to the fisheries management process. The users will vary by country, province, and municipality and are identified as key promoting agencies for an EAFM, or implementing groups. The EAFM promoting agency is typically the government fisheries management agency, but could also be an active stakeholder group or a NGO. The implementing group may be mandated to engage in an EAFM. Alternatively, the implementing group may be composed of practitioners working within and with governments and communities that normally facilitate capacity development, such as environmental NGOs. Irrespective, these guidelines are written for organizations and people that are responsible for implementing an EAFM.

1.3 HOW CAN THE CLIMATE AND OCEAN CHANGE GUIDELINES BE USED?

The *Guidelines* outline and discuss five steps to develop and implement an EAFM plan (Figure 1). In instances where climate change and ocean change are already issues of concern, specific activities in the planning steps of the Guidelines could be considered during the EAFM planning process. Activities to evaluate the potential vulnerability to climate and ocean change are also outlined. If climate and ocean change are not already priority issues, they can be systematically evaluated and reviewed over time, and included in the adaptive management cycle as appropriate.

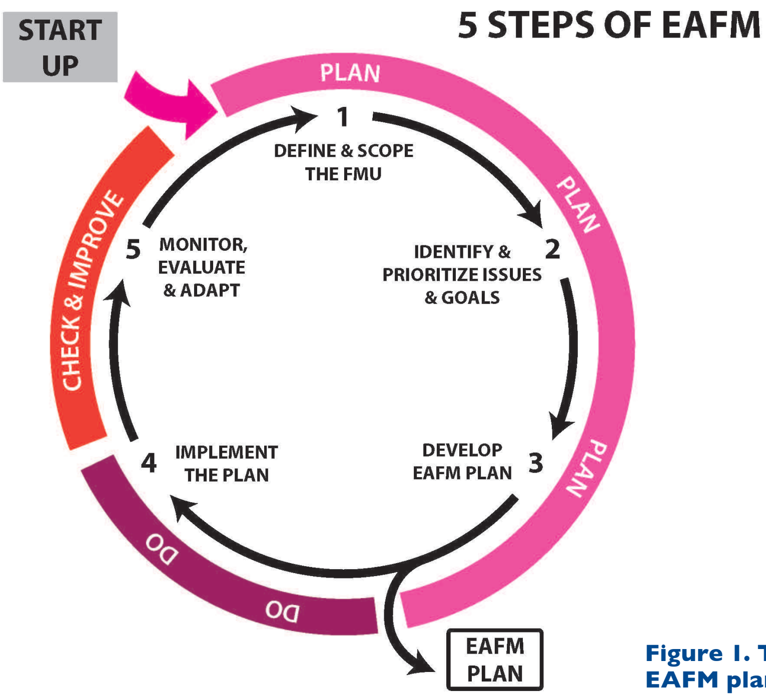


Figure 1. The five steps in the EAFM planning process.

There is no single or set method for the EAFM planning process—the activities outlined here are simply a recommended set of generic planning steps. The steps should be considered and tailored to best suit the needs and the cultural, political, and economic conditions of the management unit and coastal communities in question. The promoting agency should review and adapt the steps and activities as necessary.

When customizing the planning process for a specific area, it will be important to evaluate and build upon the management strategies already in place. If there are existing strategies for, for example, community development, climate change adaptation (CCA), integrated coastal management (ICM), local marine managed areas (LMMAs), marine protected areas (MPAs), and watershed management—which may form part of wider marine spatial planning (MSP) or ecosystem-based management (EBM) efforts—it may be appropriate to skip certain steps, or integrate existing information and products into the EAFM planning process.

Finally, the EAFM planning process is consultative throughout—it relies on effective integration of expertise, information, and decision-making across multiple sectors, stakeholders, and government agencies. All consultative actions should be adapted and conducted in a manner that best suits local and regional customs, governance structures, and decision-making processes.

1.4 AN OVERVIEW OF THE EAFM PLANNING PROCESS

An EAFM aims to balance societal and economic needs while maintaining ecological function and resilience (FAO 2009). To do this, measures are taken to manage not only the interaction between fishers and fisheries resources but the impact that fishing can have on habitats and ecosystems, as well as the impact that other sectors have on fisheries. The fundamental difference between an EAFM and traditional approaches to fisheries management is that rather than focusing on a specific fisheries resource (species) throughout its distribution, EAFM is a place-based management approach that strives to manage multiple activities that directly or indirectly affect local fisheries. The definition of the management area, or Fisheries Management Unit, is crucial to effective implementation of an EAFM because it provides for managing an ecosystem rather than jurisdictional or political boundaries. For more detail, see the companion *Coral Triangle Regional Ecosystem Approach to Fisheries Management (EAFM) Guidelines* (or FAO 2009 and UNEP 2011).

The practical implementation of an EAFM revolves around a cycle of five steps: Pre-step: start-up tasks; Step 1: define and scope the Fisheries Management Unit (FMU); Step 2: identify and prioritize goals; Step 3: develop the EAFM plan; Step 4: implement the plan; and Step 5: monitor, evaluate, and adapt. At the heart of the EAFM process is the EAFM plan, which is an integrated fisheries management plan. This plan integrates the activities of different sectors and stakeholders that directly and indirectly affect coastal ecosystems and fisheries to achieve sustainable resource management. By definition, an EAFM is participatory, with stakeholder involvement throughout the planning and management process; management is adaptive; and the plan will contain broad (holistic) objectives relevant to the Fisheries Management Unit (FMU).

The process described here for integrating adaptation and mitigation of the ecological and socioeconomic impacts of climate and ocean change provides adds additional considerations to the EAFM planning process. In particular, it addresses the need to assess the impacts of a changing climate and ocean, which over time should become an implicit part of the EAFM process.

1.5 SCOPE OF THESE GUIDELINES

The guidance outlined here is targeted at the small-scale coastal fisheries of the Coral Triangle region, which are based on both bottom-dwelling and near-shore pelagic species. However, the solutions and adaptations that arise in an EAFM focused on small-scale coastal fisheries will likely include other resources like tuna, and other sectors, e.g. aquaculture. The Secretariat of the Pacific Community (SPC) and the Western and Central Pacific Fisheries Commission (WCPFC) acknowledge that more of the tuna resources of the region need to be allocated to local food-security needs (SPC 2008) and the Pacific Islands Forum Fisheries Agency (FFA) has long promoted an ecosystem approach to managing tuna resources (www.ffa.int).

SECTION 2

HOW IS THE CLIMATE IN THE CORAL TRIANGLE EXPECTED TO CHANGE?

The Intergovernmental Panel on Climate Change (IPCC) is a United Nations effort to periodically synthesize the most up-to-date scientific information to make projections about how the climate may change over time and how those changes may impact society at global and regional scales. The Earth's physical climate system is driven by variation in natural internal processes (e.g. El Niño), external influences (e.g. volcanic activity, variations in solar output, earth-sun orientation), and human activities (e.g. greenhouse gas emissions, human-sourced aerosols, ozone depletion, and land-use changes). The IPCC projections are based on physical climate models in response to different global development and greenhouse gas scenarios.

The IPCC Fourth Assessment Report (AR4) provides the most complete summary of climate change effects for the Coral Triangle region to date (IPCC 2007). Currently, there is a global effort to analyze the model outputs in preparation for the IPCC 5th Assessment Report for release in late 2013. For an accessible description of how models are used as tools to predict climate change, refer to Bell et al. (2011: Chapter 1 Section 1.8.2).

Two issues need to be highlighted when interpreting the current climate projections for the Coral Triangle region: those of scale and uncertainty. Projected responses of the ocean and marine organisms are most robust when averaged over long time periods (e.g. 50-100 years) and broad regional areas. Uncertainty increases at smaller resolutions (local scales). In addition, model bias and the coarse resolution limits the application of model outputs to make impact assessments on living resources in limited areas (Stock et al. 2011). Furthermore, the confidence in model estimates is higher for some climatic variables (e.g. temperature) compared to others (e.g. rainfall). An aggregate multi-model approach that takes projections from a number of independent climate models is recommended to address some of these limitations (Australian Bureau of Meteorology and CSIRO 2011). With this in mind, **it is important to consider an appropriate suite of model projections for the Coral Triangle region and a range of possible planning scenarios.**

Nonetheless, models unanimously project that the Coral Triangle region is likely to experience considerable increases in sea-surface temperature (SST) and rainfall (Table 1). Over the next century, projected (SST) increases range from 1 to 4°C (depending on the specific scenario and model used). Rainfall is projected to increase in the Western Equatorial Pacific, and higher variability in rainfall is expected. However, year-to-year climatic variability in the region is strongly affected by El Niño-Southern Oscillation (ENSO) events, and IPCC-AR4 models do not agree as to whether ENSO events will become more or less frequent. Multiple models agree that the most intense **tropical cyclones will become more frequent globally, but there is no consensus as to where these more intense events will be located (Australian Bureau of Meteorology and CSIRO 2011). Global sea-level rise was conservatively estimated as at least 30-60 cm in AR4, but large deviations among models make the regional distribution of sea-level rise uncertain. More recent research efforts suggest that sea-level rise over the next century could be as much as ~1 m (Lowe and Gregory 2010, Rignot et al. 2011, Meehl et al. 2012, but see Kerr 2009), or greater (Australian Bureau of Meteorology and CSIRO 2011).**

The AR4 projections outlined above and shown in Table 1 will soon be superseded by the IPCC Fifth Assessment Report in 2013/2014. The AR5 will also contain a multi-model data set, including a new class of model, called Earth System Models (ESM). These ESMs differ from the models used in the AR4 in that they project changes in biogeochemical cycles and ecosystems, including parameters such as chlorophyll, nutrients, productivity, and ocean change, like oxygen levels. Regional projections on the physical and biogeochemical conditions for the Coral Triangle from one of the state-of-the-art ESM models developed for AR5 are outlined below. These projections are based on the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) version 2 Earth System Model using the Modular Ocean Model (ESM2M; Dunne et al. 2012a; Dunne et al. 2012b).

"models unanimously project that the Coral Triangle region is likely to experience considerable increases in sea-surface temperature (SST) and rainfall"

ESM2M predicts a strong intensification of the Pacific basin-scale atmospheric meridional overturning (Hadley circulation), and west-east overturning (Walker circulation) with equatorial uplift centered on the warmest waters. Both circulations interact strongly with ENSO over the Pacific Ocean. Intensification of these circulation patterns serves to **increase rainfall, decreases surface salinity, decreases direct visible light (more clouds)** (Fig. 2), and **decreases trade winds and currents in the high-rainfall region north of Papua New Guinea (PNG) while increasing winds over Indonesia** (Fig. 3). The combination of **increased stratification and decreased wind-driven ocean mixing leads to decreased nutrient supply from deeper nutrient-rich waters and decreased net productivity in the Central and Western Pacific Ocean** (Fig. 3), with the opposite happening west of Indonesia in the Indian Ocean. At the same time, **open ocean uptake of CO_2 (which results in ocean acidification) is expected to result in a 50 percent decrease in the aragonite saturation state** (Fig. 3). Aragonite is a form of calcium carbonate used by corals and other calcifying organisms (e.g. mollusks) to build their skeletons and shells.

" . . . it is important to consider an appropriate suite of model projections for the Coral Triangle region and a range of possible planning scenarios."

It is important to recognize, however, that these results are from only a single model, and that more rigorous analysis should be conducted across a multi-model AR5 ensemble. However, some models will reproduce aspects of the climate system better than others in different regions (Stock et al. 2011); therefore, model choice should take into account the skill of the model in predicting climate variables of interest in the CTI region. As these models continue to be developed and the spatial and temporal resolution improves with anticipated increases in computing power, we expect that **models will become increasingly useful for investigating important smaller-scale features and regional-scale representations. In the meantime, management efforts should focus on what a range of possible temperatures or sea-level-rise projections might mean for planning, rather than concentrating on specific values.**

" . . . management efforts should focus on what a range of possible temperatures or sea-level-rise projections might mean for planning, rather than concentrating on specific values."

TABLE 1. SUMMARY OF CLIMATE PROJECTIONS FOR THE CORAL TRIANGLE REGION ADAPTED FROM THE IPCC AR4 REPORT (IPCC 2007)

Values are multi-model ranges for all Special Report on Emission Scenarios (SRES)

Sea surface temperature	Sea level rise	Rainfall	Winds and tropical cyclones	Ocean circulation
Projected change: Annual, maximum, and minimum temperatures surrounding the Coral Triangle are warming (0.09-0.12 degrees Celsius per decade) and are projected to increase by 1-4° C by 2100.	**Projected change:** ~30-60 cm rise by 2100, possibly > 1 m	**Projected change:** General indication that equatorial Pacific rainfall will increase. **Projected variability:** More extreme rainfall events are likely. Inter-annual variability of monsoon rainfall may increase. Intensity of drought associated with a given rainfall deficit may be greater.	**Projected change:** No consensus on changes in location or frequency/intensity. Consensus that tropical cyclones will become more intense (with greater maximum wind speeds and heavier rainfall). Most of Coral Triangle region (except northern Philippines) is too close to equator to be significantly impacted by tropical cyclones.	**Projected change:** Relatively little information on how ocean circulation patterns will change in the Coral Triangle, but substantial changes in ocean circulation of the Tropical Pacific are expected, which will affect biological productivity. Progressive weakening of the South Equatorial Current, which will become confined to surface layers, and a strengthening of the Equatorial undercurrent in the Western Pacific, which will also become shallower directly beneath the South Equatorial Current. Note: ENSO, particularly El Niño's, significantly modulate SSTs and rainfall in the Coral Triangle. No clear consensus as to how the frequency and intensity of ENSO events will change, though the Pacific may become more "El Niño like."

FIGURE 2. PROJECTED CHANGES (ANOMALIES) OF PHYSICAL OCEAN CHARACTERISTICS FOR THE CORAL TRIANGLE REGION BY 2100

Visible light (top row, left), rainfall (top row, middle), relative humidity (top row, right), wind (middle row, left), and currents (bottom row, left) are represented as percentage change from the years 1980-1999 to 2080-2099. Air and sea surface temperature (middle row, middle and right) are in °C, sea surface salinity (bottom row, middle) in Practical Salinity Units (PSU), and sea-level rise (bottom row, right) is in meters. Model output is from the GFDL ESM2M forced with the RCP 8.5 "worst-case" scenario (Dunne et al. 2012a).

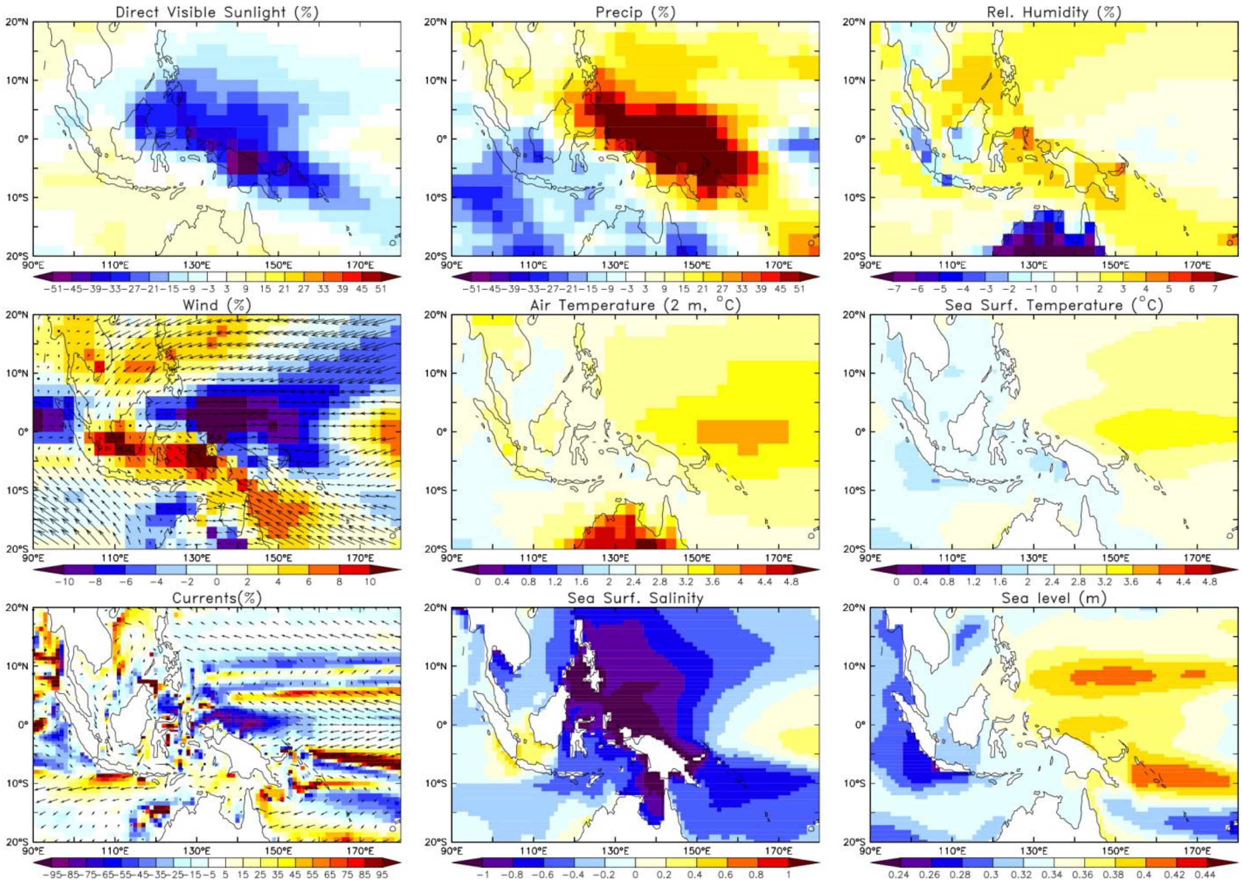
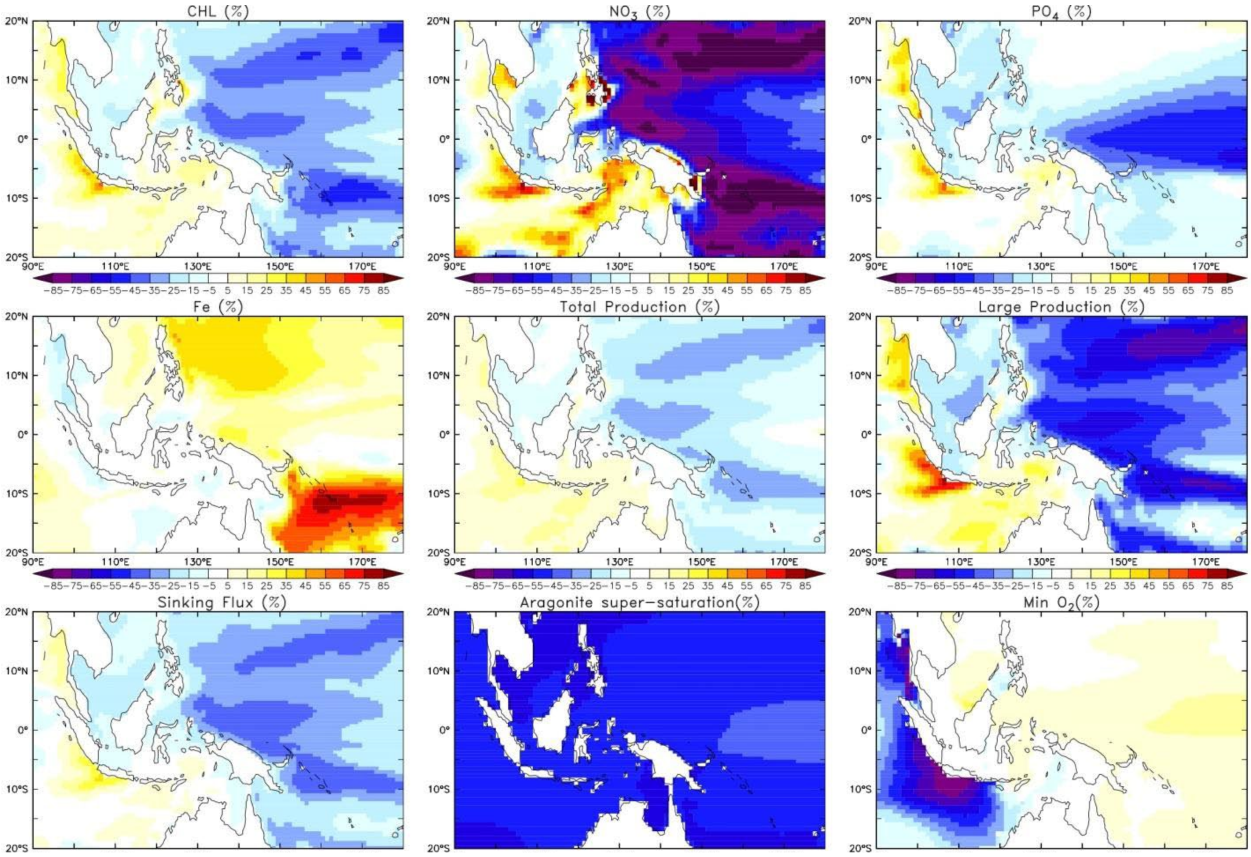


FIGURE 3. PROJECTED BIOGEOCHEMICAL OCEAN CHARACTERISTICS FOR THE CORAL TRIANGLE REGION BY 2100

Sea surface chlorophyll (upper row, left), nitrate (upper row, middle), phosphate (upper row, right), iron (middle row, left), total primary productivity (middle row, middle), large phytoplankton alone (middle row, right), sinking flux (bottom row, left), aragonite super-saturation (bottom row, middle) and minimum oxygen value at any depth (bottom row, right). All values are represented as percentage change from the years 1980-1999 to 2080-2099 using the GFDL ESM2M model forced with the RCP 8.5 "worst-case" scenario (Dunne et al. 2012b).



SECTION 3

HOW MIGHT A CHANGING CLIMATE AFFECT FISHERIES IN THE CORAL TRIANGLE?

Fisheries will experience significant impacts from climate and ocean change over coming decades, both directly through changes in the physical and chemical environment (e.g. rising ocean temperatures and decreasing pH), and indirectly through changes to habitat and food supply.

3.1 HABITAT IMPACTS

Coral reef habitat is highly susceptible to degradation from thermally-induced coral bleaching, physical damage from stronger storms, and reduced calcification due to ocean acidification (Table 2; Munday et al. 2008; Pratchett et al. 2011; Hughes et al. 2003; Guinotte et al. 2003; Hoegh-Guldberg et al. 2007, 2011). Loss of coral cover and the declining structural complexity caused by climate change and ocean acidification are predicted to have highly significant effects on reef fish populations and communities (Wilson et al. 2006; Pratchett et al. 2008; Munday et al. 2010a). There is ample evidence that the abundance of coral-dependent fishes declines sharply following coral loss (Munday et al. 2004; Pratchett et al. 2006; Wilson et al. 2006). However, population declines are not limited to coral-dependent species, with up to 65 percent of reef fish species exhibiting population declines following large-scale loss of coral cover at some locations (Jones et al. 2004; Wilson et al. 2006). Loss of structural complexity, either from storm damage or bioerosion of dead coral skeletons following coral bleaching, causes a further significant decline in abundance for many fish species (Pratchett et al. 2008), and can be associated with a reduction in species richness and taxonomic distinctness (Graham et al. 2006). Declines are often greatest for smaller-bodied species (< 20cm) that depend on the structure of reef habitat for shelter (Graham et al. 2008). Nevertheless, loss of critical habitat for small reef fishes can also affect larger predatory species. For example, Wilson et al. (2008) found that prey availability associated with the degree of habitat complexity was a more important driver of total piscivore abundance than fishing pressure on reefs in Fiji. Abundances of some herbivorous species may initially increase following coral loss, presumably due to increased food availability (Wilson et al. 2006), but even these species may decline following loss of habitat structural complexity. Small generalist species and rubble-dwellers are expected to increase in abundance as these types of habitat become more widespread on degraded reefs (Bellwood et al. 2006). Of all the potential effects of climate change and ocean acidification on reef fish assemblages, habitat degradation is predicted to be the most significant and have the most immediate impact (Munday et al. 2010a; Pratchett et al. 2011).

TABLE 2. PREDICTED IMPACTS OF CLIMATE CHANGE AND OCEAN ACIDIFICATION ON POPULATIONS AND COMMUNITIES OF REEF FISHES IN THE CORAL TRIANGLE

Levels of certainty based on expert judgment. Modified from Munday et al. 2010a

Impact	Physical driver/s	Details	Certainty
Reduced abundances and changes to community composition of reef fishes	Loss of coral cover and declining structural complexity of habitat from coral bleaching, increased storm damage, and reduced calcification rates of corals and crustose coralline algae	Sharp declines in abundance of coral-dependent species and species that prefer to settle near live coral. Longer-term declines in abundances of other species as habitat structure decreases. Increased abundance of some herbivores, small generalist species, and rubble-dwellers.	High
Change to fish community structure	Increased temperature	Species composition will change due to inter-specific differences in tolerance to higher temperatures.	High
Reproductive decline	Increased temperature	Some low-latitude species will experience reduced reproductive performance.	Moderate
Life history modification	Increased temperature	On average individuals will tend to grow faster during early life, reach smaller maximum sizes, and be shorter lived. Effect size may be small compared to existing natural variation in life history traits.	Moderate
Reduced pelagic duration	Increased temperature	Small increases in water temperature will tend to accelerate larval development and competency to settle. Larger increases in temperature may be detrimental to embryonic or larval survival. Changes to larval duration and/or survival probability could influence population connectivity.	Moderate
More extremes in recruitment	Increased temperature and changes in primary productivity and ocean circulation	Shorter pelagic durations and faster larval growth will tend to reduce larval mortality. However, higher metabolic rates will increase the risk of starvation where food supply is limited. Highly variable and unpredictable—some locations may tend to have better recruitment and others poorer recruitment.	Moderate
Reduced productivity	Increased temperature and changes in ocean circulation	Less nutrient enrichment due to greater stratification of surface waters in combination with increased metabolic demands of consumers could reduce productivity at higher trophic levels. Highly variable and unpredictable—productivity may increase at some locations.	Moderate
Behavioral and sensory impairment	Ocean acidification	Elevated CO_2 levels could affect homing ability, habitat selection, and predator avoidance of larval, juvenile, and adult fish.	High

There is less information available on the observed effects of climate change on seagrass meadows, mangroves, and intertidal reef flat habitats. Despite the importance of these coastal habitats as nursery areas for juvenile fish and invertebrates and as primary habitats for important fisheries species, there is a real lack of information on both the extent of these habitats and the potential effects on climate change. Bearing this knowledge gap in mind, of the projected variation in environmental conditions sea-level rise is likely to have the most significant impact on mangrove habitats. A landward retreat is expected, as mangroves are unlikely to be able to accumulate sediment at the rate necessary to keep up with the rise in sea level (Waycott et al. 2011). Sea level rise is also expected to lead to a loss of deep-water seagrass habitats present at edge of their depth limits; otherwise, only a moderate loss of seagrass habitat is expected due to the combined changes in other environmental variables (Waycott et al. 2011).

3.2 BIOLOGICAL IMPACTS OF TEMPERATURE CHANGE ON INDIVIDUALS, LARVAL SUPPLY AND POPULATIONS

Temperature changes of just a few degrees Celsius can influence the physiological condition, developmental rate, growth rate, reproductive performance, and behavior of fishes (Munday et al. 2008). Consequently, rising sea temperature could have a range of important ecological ramifications for reef fish populations and communities (Table 1). Recent studies show that there is significant variation in the sensitivity of different coral reef fish species to elevated water temperature. While the physiological performance of some species declines dramatically with an increase of 2-3°C (Nilsson et al. 2009; Donelson et al. 2010), other species appear more tolerant. Consequently, the composition of local fish communities are expected to change as the more thermally-sensitive species decline in abundance and probably shift their distributions to higher latitudes where temperatures will be more favorable. Furthermore, most fish reproduce within a narrow temperature range and declines in reproductive output are likely (Donelson et al. 2010; Pankhurst and Munday 2011), especially for low-latitude populations that have little opportunity to shift the timing of breeding to more favorable seasonal temperatures (Srinivasan and Jones 2006).

Reduced reproductive effort could have significant effects on the replenishment of fish populations. In general, the effects of rising water temperature on the sustainability of fish populations at specific locations are expected to be most noticeable in low-latitude populations, which appear to be living close to their thermal optimum and have less capacity to cope with future temperature increases compared with populations from higher latitudes (Gardiner et al. 2010). In addition to the poleward shift in the distribution of more thermally-sensitive species, a deepwater shift may also occur. In the western rock lobster fishery in Australia, increased temperature may have contributed to the decrease in size at maturity and decrease in the abundance of undersized and legal-sized lobsters in shallow water, with a shift in catch to deep water observed over the last 35-40 years (Caputi et al. 2010). A recent modeling study that accounts for inferred thermal tolerance of a wide range of marine fishes and invertebrates projects a high rate of local extinction of these species in low-latitude regions under a scenario of doubling of carbon dioxide by 2100 relative to the 2000 level (Cheung et al. 2009).

Environmental factors are already major drivers of variation in fish and invertebrate larval supply and recruitment. Life history traits of exploited marine fish and invertebrates, such as growth rate and maximum size, will be affected by rising ocean temperature, with potential implications for fisheries yields (Cheung et al. 2010, 2011), although these effects may be difficult to detect against natural variation in life history traits and fishing effects among locations without long time-series data. Another concern is that higher ocean temperatures could lead to increased recruitment variation and more recruitment failures (Munday et al. 2008). Although a small increase in temperature may accelerate larval growth and development (O'Connor et al. 2007), it will also increase metabolic rate and make larval fish more susceptible to starvation. When combined with a possible reduction in primary productivity due to increased stratification of the surface ocean (Cheung et al. 2010), there is likely to be a greater risk of larval failing to find adequate food resources. The combined effects of elevated temperature on adult reproduction and the survival of larvae in the plankton could have a highly significant impact on the supply of recruits to replenish benthic populations (Loy-Yat et al. 2011), although such impacts are likely to be spatially and temporally variable and difficult to predict (Munday et al. 2008). Projected weakening in the velocity of the South Equatorial Current and the South Equatorial Counter Current (Ganachaud et al. 2011) near Papua New Guinea and Solomon Islands can also be expected to affect larval fish supply through altered patterns of larval dispersal and "homing" behavior of larval fish (Pratchett et al. 2011).

3.4 BIOLOGICAL IMPACTS OF OCEAN CHANGE

Although fish generally appear to be tolerant to ocean acidification (Ishimatsu et al. 2008; Melzner et al. 2009; Munday et al. 2011), recent studies have demonstrated that levels of CO_2 predicted to occur in the surface ocean by the end of this century can impair sensory functions and alter the behavior of larval, juvenile, and adult reef fishes (Munday et al. 2009; Dixson et al. 2010; Simpson et al. 2011; Nilsson et al. 2012). Habitat selection, homing ability, and predator avoidance are all affected by exposure to high CO_2 (Munday et al. 2009; Dixson et al. 2010; Simpson et al. 2011; Devine et al. 2012a,b). Most notably, behavioral changes affect predator-prey interactions, leading to higher mortality rates of new recruits and juveniles, with potential consequences for population replenishment (Munday et al. 2010b; Ferrari et al. 2011). The effects of ocean acidification are expected to have the greatest impact on invertebrates, due to their calcium carbonate shells and skeletons; however, the adaptive capacity of species to ocean acidification is not well understood and there is large variation across different taxa (Kroeker et al. 2010, 2013). The development of weaker shells under more acidic conditions, as observed in larval oysters (Miller et al. 2009), could lead to a decrease in the successful recruitment and an increase in predation on invertebrate species (Pratchett et al. 2011). Increased predation on coral recruits reared in acidic conditions has been observed, along with a shift in the size at which recruits are less vulnerable to predation (Doropoulos et al. 2012). How this will manifest into larger-scale habitat impacts over time is not understood, and a major limitation in our ability to predict the impacts of climate change and ocean acidification on fisheries populations and communities is a lack of information on the capacity for acclimation and adaptation. Although tropical species are generally considered to have less capacity for acclimation and adaptation to climate change than temperate species (Stillman 2003; Tewksbury et al. 2008), new studies have revealed remarkable potential for long-term trans-generational acclimation to elevated temperatures in one reef-fish species (Donelson et al. 2012). Further studies will be required to determine if similar capacity to adjust to climate change over multiple generations occurs in other species.

3.5 FISHERIES YIELD IMPACTS

Climate change and ocean change are expected to affect fisheries yields (Sumaila et al. 2011; Pratchett et al. 2011). Growth of fish and invertebrate populations are dependent on temperature. Under ocean warming, the increased metabolic demand is expected to lead to a reduction in the maximum body size (Cheung et al. 2011). Warming will shift the environment away from the optimal conditions for some species and negatively affect their growth and recruitment. Such impacts may be exacerbated by ocean acidification (Denman et al. 2011). Simultaneously, primary production that is available for fish stocks is affected by various aspects of climate change, such as changes in temperature and wind stress (Le Borgne et al. 2011). The global Earth System Models project a reduction in primary production in the tropics by the end of the 21st century (Steinacher et al. 2010), although such projections have low representation of coastal and shelf seas (Stock et al. 2011). The climate change-induced degradation of habitats will also affect the abundance and productivity of fish stocks. The consequences of the combined effect of these changes include an overall reduction in maximum catch potential in low-latitude regions (Cheung et al. 2010). Particularly, areas that are strongly dependent on mollusk fisheries are vulnerable to ocean acidification-driven decreases in fisheries (Cooley et al. 2012). The bottom-up effects of global climate and ocean changes are likely to interact with the top-down effects of fishing, exacerbating the overall impacts (Ainsworth et al. 2011; Griffin et al. 2011).

3.6 SEA LEVEL RISE IMPACTS

The ecological impacts of sea-level rise will vary depending upon the geological character of the shoreline and topography. Where topography is low and/or shoreline sediments are easily eroded, there will likely be significant sedimentation and decreased water quality that could impact coral reef and other sensitive habitats (Blanchon et al. 2009). Greater inundation of reef flats can erode residual soils and lagoon deposits (Adey et al. 1977; Lighty et al. 1978) and produce greater sediment transport (Hopley and Kinsey 1988). In low-lying developed coastal areas, people may either need to vacate areas over time or invest in the construction of, for example, seawalls and levees or repairing and relocating shore-based facilities; however, flood defense mechanisms could disrupt, for example, natural sediment transport cycles. Longer term, the hardening or development of the shoreline could prevent the landward migration of coastal habitats; wetland and coastal development should, therefore, allow for the gradual movement of habitats in response to rising sea level. Coastal communities may also experience the salinization of irrigation water, freshwater, and estuarine habitats, posing significant health risks due to a reduction in the availability of freshwater.

Over the longer term, the impacts of sea-level rise will not necessarily be negative, raising water levels above existing reef flats and by shoreward migration of coastlines could also provide increased overall area for many shallow-water habitats and the marine species and ecosystems that they support. The influence of sea-level rise is likely to have mixed responses for many marine species depending on their depth preferences, sedimentation tolerances, growth rates, and the near-shore topography. In summary, sea-level rise is an inevitable effect of climate change, but as discussed above, the extent and consequences remain somewhat uncertain. We do, however, know which areas will be most vulnerable: low-lying coastal communities.

3.7 SOCIOECONOMIC IMPACTS OF CLIMATE AND OCEAN CHANGE

The impact of climate change on the fisheries sector in socioeconomic terms is difficult to assess, not only because of the great uncertainty regarding the extent and rate of climate change, but also due to the uncertainty surrounding the impacts on biophysical processes and how these propagate upwards through ecosystems to harvest stocks or use ecosystem services (Daw et al. 2009). There is a high dependence on fish and fish products for food and livelihoods in the Coral Triangle region (Foale et al. 2012; Bell et al. 2009). Fish constitute a high proportion of export income in parts of Asia, and a major source of dietary protein—typically 40 percent of all animal protein consumed per year. It is important to note that socially and economically important environmental changes result not simply from climate change but from interactions between climate, ecosystem, and resource usage. Environmental changes affect people differently and through interactions with various social, economic, and institutional factors (Daw et al. 2009).

Arnason (2003) proposed that climate change may impact fisheries in at least two different ways: by altering the availability of fish to fishers (direct impact) and by changing the price of fish products and fisheries inputs (indirect impact). Previous research has demonstrated the economic impact on fisheries through changes in climate. International studies have projected the displacement of several million people from the region's coastal zone in the event of a 1-m rise in sea level. The costs of response measures to reduce the impact of sea-level rise (30-50 cm) in the Coral Triangle region could amount to many millions of dollars per year. Climate shocks on Asia-Pacific fisheries are predicted to have significant economic and food security consequences for the poorest people in the region (Briones et al. 2005).

Changes in the availability of fish and fish products, through stock redistribution and abundance, can affect total revenues and harvesting costs (net revenues) of fishers, thus influencing the choice of target species. Fluctuations in sea-surface temperatures have been shown to have significant effects on fishing effort (Gillet 2003). Changes in fish distribution and availability can increase travel time and lead to increased fuel and ice costs.

As species distributions change in response to climate change, small-scale fishers may be less able to adapt by following them because of limited mobility. Pinsky and Fogarty (2012) reported on the economic and regulatory constraints on the ability of fisheries to keep apace with the northward shift in species distribution as observed over 40 years in the Northeastern US. These constraints will likely also apply, with the potential to be felt more strongly by small-scale fishers, such as those in the Coral Triangle. Traditional area-based access rights institutions will become strained by the loss or relocation of local resources. However, while some fisher folk will see the disappearance of their target species, others could see an increase in landings of species of high commercial value (Badjeck 2008).

A reduction in exports can cause a great deal of hardship in already strained fishing industries in the non-Pacific Island countries of the Coral Triangle (Indonesia, Malaysia, Philippines, and Timor-Leste) and generate adverse long-term economic consequences (Caviedas and Fik 1992).

A reduction in financial capital, for instance access to credit and loans, has been observed as a consequence of climatic variability. As a result of decreasing catches, government financial resources can be reduced, leaving fishers without a safety net and access to financial resources to cope with the difficult economic situation.

Increases in storms and floods can lead to decreased fishing capacity and decreased access to markets. Storm and severe weather events can destroy or severely damage infrastructure and equipment such as port, landing sites, and boats. While infrastructure damages are recoverable, the time necessary for such an endeavor can be critical for the fisheries sector and in countries where state assistance is minimal and financial capital limited the impact of extreme events could be damaging in the longer term.

In general, small-scale fishers in the Philippines, Malaysia, Indonesia, and Timor Leste will be particularly vulnerable to the direct climate-change impacts because they tend to live in the most seaward communities and are thus at risk from damage to property and infrastructure from multiple direct impacts such as sea-level rise, increasing storm intensity and frequency. There are no projections for increased storm frequency in Papau New Guinea and the Solomon Islands. Furthermore, the worsening storms—for example, in the Philippines—may also increase the risks associated with working at sea, and changes in weather patterns may disrupt fishing practices that are based on traditional knowledge of local weather and current systems.

Disruption of other sectors (e.g. agriculture, tourism, and manufacturing) by extreme events could lead to indirect socioeconomic effects. The displacement of labor into fishing can lead to conflicts over labor opportunities and increased fishing pressure. Droughts and resultant agricultural failure may lead to so-called "environmental refugees" moving to coastal areas and creating an influx of surplus fishing labor.

The livelihoods of small-scale fishers are already vulnerable to a range of non-climate risks, including fluctuating resources, loss of access, HIV/AIDS, market fluctuations, conflict, political marginalization, and poor governance (Allison et al. 2008). This insecurity inhibits investment in long-term strategies for sustainable fisheries and will be exacerbated by additional insecurities caused by climate change impacts. Small-scale fishers also generally lack insurance.

Environmental changes affect people differentially and through interactions with social factors. Social networks and cohesion (social capital) are important, in addition to skills (human capital), investments (physical capital), and alternative resources (natural capital): all shape how the benefits and costs are distributed. (Hamilton et al. 2003).

The socioeconomic effects of ocean change are hard to determine but could amount to many billions of dollars.

SECTION 4

CLIMATE AND OCEAN CHANGE VULNERABILITY ASSESSMENT FOR AN EAFM

4.1 WHY DO A VULNERABILITY ASSESSMENT?

If you are concerned about how climate and ocean change may affect plans to use fisheries resources in a sustainable way, then performing a vulnerability assessment is a way to better understand these effects. A climate change vulnerability assessment is an instrument for the systematic examination of who and what is vulnerable, to what and why. In doing so, vulnerability assessments facilitate adaptation to climate and ocean change by identifying the implications to marine resources, fisheries, food security, livelihoods, and the economy more generally. To achieve this, both the direct effects of climate change on fish stocks and the indirect effects on their supporting habitats need to be investigated. To be most effective, the results of the climate change vulnerability assessment need to be a part of the adaptive management process; specifically, they will need to be systematically reviewed and updated over time when new information becomes available, like the IPCC Assessment reports, or as conditions within the FMU may change over time. To deal with the inevitable but uncertain effects of climate change in fisheries, the ongoing process of performing climate change vulnerability assessments will be a key part of an EAFM.

4.2 WHAT IS VULNERABILITY AND HOW DO YOU MEASURE IT?

The vulnerability of coastal human communities or natural systems to climate and ocean change can be considered as the level of susceptibility to harm by events such as coral bleaching, storm damage, and sea-level rise (Gallopin 2006). Vulnerability is calculated by integrating three measures; exposure, sensitivity, and adaptive capacity. Following the definitions of Marshall et al. (2010), exposure is the extent to which a system comes into contact with climate hazards, or specific climate impacts. Sensitivity is the degree to which a built, natural, or human system is negatively affected by changes in climate conditions (e.g. temperature and rainfall) or specific climate or ocean change impacts (e.g. sea level rise, increased water temperature). Adaptive capacity is the potential, capability, or ability of built, natural, and human systems to adapt to impacts of climate change and variability with minimal potential damage or cost. Thus, assessing an area's vulnerability to the impacts of climate and ocean change involves understanding: 1) the climate projections for a given region or area, 2) what is at risk (climate change exposure and sensitivity), and 3) the capacity of the ecosystem (both natural and human) to cope with the expected or actual climate changes (adaptive capacity). Combined, these three factors define the vulnerability of people, fish, and ecosystems in a place to climate and ocean change.

The vulnerability of marine ecosystems, fisheries, and economies will be location specific and a number of the EAFM decisions which affect vulnerability are often made at a local Fisheries Management Unit level, which is the focus here for vulnerability assessments. Currently, the science for predicting change in climate parameters is reasonably well defined; for example, there already exist national vulnerability assessments for Papua New Guinea and the Solomon Islands, which include the projected changes in sea-surface temperature, sea level, ocean pH, currents, and nutrient supply (Bell et al. 2011). Regional predictions of climate parameters and how they will vary over time (see Section 2: How is the climate in the Coral Triangle expected to change?)

can be used to explore different future climate scenarios in a vulnerability assessment for a particular Fisheries Management Unit areas. Because the purpose of the vulnerability assessment at the scale of the Fisheries Management Unit area will be to provide specific information that can guide local decision making, local stakeholders will be integral to selecting vulnerability indicators. Local-level information can be used to select criteria that will mirror stakeholders concerns and the decision-making process in the Local Management Unit area (Naess et al. 2006).

A vulnerability assessment is a tool to better understand how climate change threats will impact important natural and social resources and systems such as coastal habitats and ecosystems, fisheries, human settlements, human health, freshwater resources, and economics activities such as tourism. For EAFM, a fisheries climate-vulnerability assessment (for example, US CTI Support Program [2013] LEAP Guide), as coastal community and fisheries systems vulnerabilities (social and ecological) and adaptive capacity are intrinsically linked. Together, this can inform the adaptation options within a community development plan, as coastal communities will experience a wide range of hazards that will include climate and non-climate threats, like man-made hazard events, from natural processes (earthquakes, tsunamis, king tides), man-made hazard events (hazardous material and oil spills), in addition to climate change-related threats (sea level rise, storm surge, ocean acidification). A fisheries vulnerability assessment can be done at a national level, sub-national or a more local level. Vulnerability assessments normally assess a coastal areas vulnerability to climate change at the municipal or community level. While community vulnerability assessments will normally consider climate-change threats to the fisheries and associated habitats and ecosystems, the information obtained may not be as detailed as suggested in these guidelines.

Multiple sectors should be involved in the climate-change vulnerability assessment process to include the full breadth of users and government agencies that might be affected and be part of the EAFM plan in future changing climate conditions. To illustrate, consider the comprehensive list of groups that were involved a vulnerability assessment training workshop hosted by the Office for Climate Change in the Solomon Islands. The workshop was on how to use SimClim, a climate change and adaptation program that uses climate and sea-level rise scenarios to explore the impacts on rainwater, agriculture, and coastal zone impacts. This workshop included representatives from: the Disaster Management Office; Solomon Islands Met Service; Red Cross; Ministry of Agriculture and Livestock; Department of Forestry; Commodities and Export Marketing Authority; Department of Tourism; Ministry of Lands, Housing and Survey; Ministry of Mines, Energy and Rural Electrification; National Council of Women; National Adaptation Program of Action; Ministry of Fisheries and Marine Resources; Ministry of Environment, Conservation and Meteorology; and Rural Water and Sanitation. A mix of national and local government representatives should be present, especially in countries where coastal and fisheries management has been devolved and there are traditional customary laws and regulations.

There are a number of other vulnerability assessment tools available for fisheries and associated habitats (see www.ebmtools.org). For example, FISHBE (Alino 2007; Licuanan et al. 2006), Climate Change Vulnerability Assessment for Fisheries Ecosystems (Glick et al. 2011), the Tool for Understanding Resiliency in Fisheries (TURF) (Mamauag et al. 2012), and the Coastal Integrity Vulnerability Assessment Tool (Siringan 2012), the Coastal Assessment Tool and Planning Software (COASTPLAN) (Cabral et al. 2010). For an overview and comparison of the vulnerability assessment approaches for fisheries available see (Johnson and Welch 2010). A database of climate change vulnerability assessment and adaptation tools is available on the Ecosystem Based Management Tools Network (www.ebmtoolsdatabase.org).

SECTION 5

INCLUDING CONSIDERATIONS OF CLIMATE AND OCEAN CHANGE INTO AN EAFM

5.1 OVERVIEW OF THE EAFM MANAGEMENT CYCLE AND ITS RELEVANCE TO CLIMATE CHANGE

The following five steps (plus an initial pre-step) make up the EAFM planning process. The purpose of the pre-step is to conduct preparatory activities to get organized and to identify and initially engage with the stakeholders. The pre-step can be thought of as an entry point into the EAFM management cycle and from this point on the management cycle is adaptive. During adaptive management there are three different phases: plan, do, and check and improve. During the "planning phase" (step 1–3) are carried out to develop the EAFM plan. The "doing phase" involves the actual implementation of the plan (step 4). The "checking and improving phase" (step 5) is the cornerstone of adaptive management. Monitoring is performed to assess the consequences of the management actions implemented as part of the plan. This information can then be used to evaluate how close the fisheries management unit is to the management targets specified as part of the plan. The monitoring and evaluation part of step 5 provides an opportunity for informed management decisions that are adapted over time as the evaluation of the EAFM plan is communicated with stakeholders and this information is used to revise and update the plan, and so the cycle begins again.

PRE-STEP: Start-Up

A. Prepare the Ground

B. Engage Stakeholders

PLAN

STEP 1. Define and Scope the Fisheries Management Unit (FMU)

STEP 2. Identify and Prioritize Issues and Goals

STEP 3. Develop the EAFM Plan

DO

STEP 4. Implement the EAFM Plan

CHECK & IMPROVE

STEP 5. Monitor, Evaluate and Adapt

An EAFM aims to secure sustainable fisheries by balancing ecological and societal well-being (Curtis et al. 2011). Ecological well-being might refer to changes in species distribution or habitat structure, while societal well-being could refer to employment and food security. An EAFM is not an entirely new management framework, but rather an evolving extension of existing efforts. By design, an EAFM provides a flexible management process, and thus is well suited to managing fisheries in a changing climate, because of the uncertainty over the predicted impacts of climate change and ocean change on marine ecosystems and the associated fisheries. The principles of an EAFM very much compliment what will define fisheries that are resilient to the impacts of climate change and ocean change. For example, an EAFM aims to restore ecosystem structure and function, and systems with intact ecological functions are predicted to be better able to absorb, withstand, and recover from changes in environmental conditions (Green and Bellwood 2009).

5.2 HOW DO YOU INCLUDE CONSIDERATIONS OF CLIMATE CHANGE AND OCEAN CHANGE INTO AN EAFM?

Outlined below are the five steps in the EAFM planning process which are taken from the accompanying document, *Coral Triangle Regional Ecosystem Approach to Fisheries Management Guidelines*. Here, the steps where climate change and ocean change need to be specifically considered are highlighted and discussed.

PRE-STEP

A. PREPARE THE GROUND

A1. IDENTIFY EAFM TEAM AND FACILITATORS – In order to implement an EAFM plan that considers climate change and ocean change, it is first essential to ascertain whether the EAFM team has an appropriate level of climate change expertise and awareness. The team should come from available and interested parties, including representatives of the local, provincial and national government, academe, private sector, environment officers, legislators, village leaders, fishers leaders and women representatives where available.

A critical step towards being able to incorporate climate change into fisheries management is an acceptance and understanding that these changes are occurring and will continue to occur. Two key questions will help identify whether the EAFM team is in a position to efficiently develop an EAFM plan that incorporates the effects of climate change and ocean change:

- Why do we want to develop an EAFM/COC plan that considers climate and ocean change impacts at this time?
- Are we ready?

The EAFM team needs to evaluate whether at that specific time they are in a position to accurately convey the complexity and champion the inclusion of climate and ocean change into the fisheries management plan for their Fisheries Management Unit. A suggested approach to tackling these questions is outlined in Step 1 of the US CTI Support Program (2013) LEAP Guide (see Appendix B). The aim of this activity is for the EAFM team to assess whether they are prepared with the right information and if now is the right time to initiate the development of an EAFM plan that considers climate and ocean change, or alternatively if more activities (such as climate awareness training) need to be carried out to get organized.

While no specific technical expertise in climate change and ocean change is required to carry out the basic EAFM planning process, technical assistance will likely be helpful at particular points in the process.

External (to the EAFM team and stakeholder group) scientific and technical support will probably be needed to 1) understand the climate projections for the area; 2) select appropriate adaptation strategies for specific issues—for example, how to deal with coastal inundation, fisheries, and habitats impacts and; 3) to improve understanding of socio-ecological vulnerability to climate and ocean change. As such, the EAFM planning team should consult with experts from academia, non-governmental organizations, and/or government as needed. Ideally such expertise should be represented in the Ecosystem Management Advisory Group (see step 1.5) to help assess the feasibility of the evolving EAFM plan and identify the most effective, positive actions for incorporating considerations of climate and ocean change throughout the communities in the Fisheries Management Unit .

A2. DEVELOP START-UP WORK PLAN – In developing the start-up work plan, issues of climate and ocean change should be discussed and considered with the stakeholders at this early stage in order to determine if it is a concern for later action in the EAFM management plan.

A3. IDENTIFY BROAD FISHERIES MANAGEMENT UNIT (FMU) AREA – In identifying the broad FMU, boundaries are established to include issues of climate and ocean change in the area.

A4. EAFM INTRODUCTION – During the early courtesy calls and meetings, concerns about climate change can be raised and discussed.

A5. COORDINATE WITH OTHER MINISTRIES/AGENCIES AND GOVERNMENT LEVELS – The EAFM guidelines outline how important it is to engage early on with the coastal and fisheries institutions at each level of government and to coordinate policies and operational guidelines amongst agencies and institutions. The same applies to the EAFM/COC plan, but the addition of climate and ocean change may require the involvement of departments that may have traditionally had only limited interaction or overlap. Cross-sectoral coordination will vary from country by country, but it is essential to identify which groups and sectors may be or should be working towards complementary solutions to issues. For example, the Ministry of the Environment may be responsible for climate change adaptation and mitigation, while the Ministry for Civil Protection is normally responsible for disaster risk management. In many instances, neither of these ministries coordinated with fisheries management agencies, yet clearly they are connected. To effectively and regularly coordinate amongst ministries and agencies, a regular coordination mechanism should be established. The first step in this process involves identifying the appropriate ministries and agencies. The second step involves identifying appropriate divisions within the ministries/agencies and then specific points of contact.

A6. IDENTIFY STAKEHOLDERS AND ORGANIZATIONS (INCLUDING VULNERABLE GROUPS TO IMPACTS OF COC) – See the EAFM guidelines for details on how to identify key stakeholders. The process of identifying stakeholders will not differ substantially when climate change and ocean change are included; however, care should be taken to be sure to consider how the wider implications of climate change may alter who is affected and who has a stake in the management plan. The US CTI Support Program 2013 LEAP outlines details on an activity that can be conducted to identifying key stakeholders, this activity could be applied to identifying stakeholders in the development of EAFM.

A7. ESTABLISH CORE CONSULTATIVE GROUP – As stated in the EAFM guidelines: "A core group is a small group of individuals from the stakeholders (perhaps four or five) who will initially work with the facilitators to guide the EAFM process. The members of the core group should represent different sectors of the community."

For the EAFM/COC planning process, it is desirable to include individuals in the core consultative group who are knowledgeable about and/or will be significantly affected by climate and ocean change.

A8. DETERMINE LEGAL BASIS FOR EAFM

B. STAKEHOLDER ENGAGEMENT

B1. ASSESS STAKEHOLDER INTEREST AND COMMITMENT

B2. COMMUNITY ORGANIZING

B3. AWARENESS RAISING AND EMPOWERMENT – If climate change and ocean change impacts are considered to be an issue and concern for stakeholders, information and awareness-raising materials can be provided.

B4. COMMUNITY MEETINGS – During these community meetings, concerns and issues of various stakeholders about the impacts of climate and ocean change can be raised and discussed.

B5. SOCIAL MARKETING

PLAN

STEP 1. DEFINE AND SCOPE THE FISHERIES MANAGEMENT UNIT (FMU)

As stated in the EAFM guidelines:

> "A successful plan requires a clear statement of the area to be managed—the Fisheries Management Unit. Ideally, the Fisheries Management Unit will coincide with a clearly and precisely defined ecosystem."

Rarely, however, is it possible to have a clearly and precisely defined ecosystem, so sometimes just decide on what is most "manageable" for the planning phase and one which has the majority of the stakeholders present that represent the decision makers of that ecosystem. You can start small and always repeat the process to add adjacent areas.

The impacts from climate and ocean change will likely occur over larger scales than the Fisheries Management Unit and the defined ecosystem. These impacts will involve potential changes to fish species, habitat distribution, and human use patterns that may occur outside the original Fisheries Management Unit boundaries. In developing and implementing an EAFM/COC plan, the team needs to assess these potential changes in distributions and habitats over time and decide if the Fisheries Management Unit boundaries need to be expanded to more effectively address the predicted changes, or if cross-boundary collaboration is needed.

A number of activities are undertaken during the FMU profile related to climate and ocean change:

ASSESSING NON-CLIMATE THREATS – Climate risks are usually part of a wider set of vulnerabilities affecting a fishery, community, or region (Hall 2011). Thus, the success of adaptation measures also requires addressing non-climatic issues and drivers of vulnerabilities at the local or Fisheries Management Unit level. In the case of fisheries, the implications of climate and ocean change might need to be viewed in conjunction with other pressures, such as poor enforcement, overcapacity of fishing fleets, overfishing, illegal fishing, poverty, globalization of trade and market access, technological advances, population growth, health, marginalization, pollution from land-based sources, and habitat degradation and destruction.

To assess non-climate threats, there are two main exercises:

- mapping the FMU and community, and
- developing a threat action model.

These two exercises form part of the US CTI Support Program (2013) LEAP Guide.

MAPPING THE FISHERIES MANAGEMENT UNIT AND COMMUNITY – A map is made that can be used for multiple purposes throughout the EAFM planning process. The map is created by the EAFM team in collaboration with the core stakeholder group. The area of the map should span the entirety of the Fisheries Management Unit and areas likely to be impacted by climate change and ocean change. Climate experts within the Ecosystem Management Advisory Group or equivalent should help identify sensible limits for considering the spatial extent of climate change impacts that are relevant to the Fisheries Management Unit. Since an important aspect to the process of mapping the Fisheries Management Unit is making sure the information is accessible to multiple users, appropriate formats and mediums for presentation and discussion should be considered. Geographic information systems (GIS) or other interactive mapping tools are an effective way to convey multiple layers of information, but can be limiting in terms of engagement by some stakeholders and expensive. For some groups, simpler use of overhead projectors, white boards, or large posters that large groups can view simultaneously can also be just as effective. In some instances, the construction of three-dimensional topographic table maps have served as an effective talking point and tool for community engagement.

The mapping exercise will allow the stakeholders (fishers and non-fishers) to identify the places they use, value, and need. The map should cover the entire area of the Fisheries Management Unit and where there will be possible impacts from climate change and ocean change. The location of these elements can be approximated, as more precise maps can be prepared later. The maps should include information such as: What are and where are the key habitats and species within your Fisheries Management Unit? Include terrestrial, aquatic, and marine habitats and species (e.g. mangroves, coral reefs, forests, grouper, etc.)? Identify habitat quality of each key habitat (e.g. good reef areas, damaged reef, healthy streams, polluted streams, etc.). Where are the areas that are important for key species (e.g. turtle nesting beaches, spawning aggregations)?

DEVELOPING A THREAT/ACTION MODEL – A threat/action model is used to identify the most important information about the activities that occur in an area and what can be done to better manage the non-climate threats for that area. There are three main stages to developing the model:

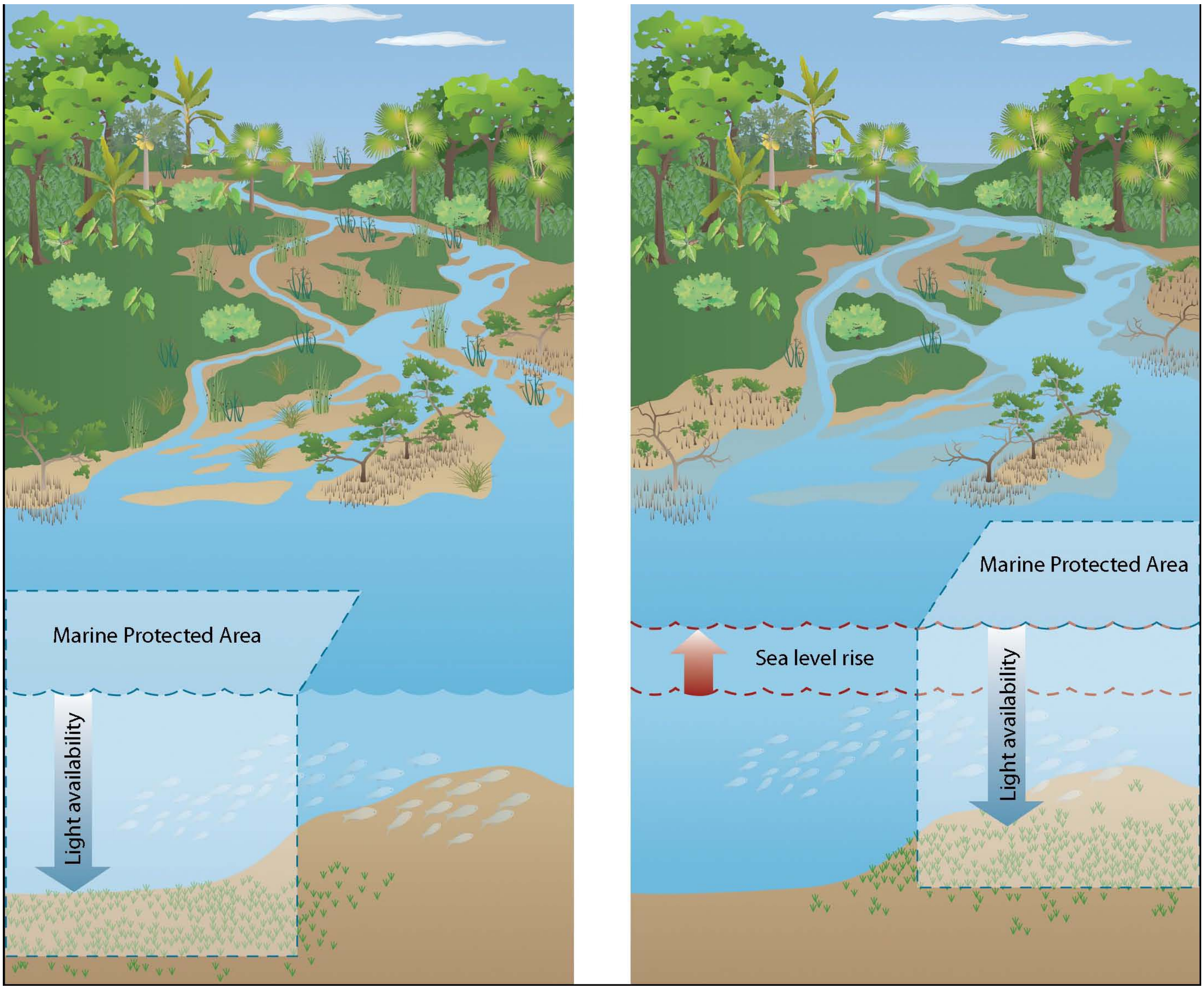
1. Identifying natural resource and social targets for the area and the location where each target is in on the map.
2. Identifying threats that prevent managing/conserving the targets. The location where each threat is taking place, and the impact and causes of each threat.
3. Identifying early actions that are doable to address issues.

GAP ANALYSIS – A gap analysis provides a framework that can be applied to assess the effectiveness of any management intervention; however, in the context of natural resource management, it is most commonly used in relation to networks of conservation areas (Jennings 2000). Spatial management measures, such as the use of marine protected areas, will likely be one of the management tools considered in an EAFM, and a gap analysis can be used to identify gaps in marine conservation areas within the Fisheries Management Unit for the management of integrated fisheries, biodiversity, and climate change objectives.

The basic concept of the gap analysis is to first identify and classify the elements to be managed in the conservation areas within the Fisheries Management Unit, whether these are focused on specific species, habitats, or other components of ecological importance (such as areas of upwelling). The existing conservation areas and numerous other data layers—including topography, bathymetry, coastal development, management boundaries, environmental information, and the like—are typically collated via GIS maps and are examined to assess the performance and shortfalls in existing management. This information is then used to adapt the existing management and conservation areas or plan for new ones. For more details on conducting a national gap analysis see http://www.cbd.int/protected-old/gap.shtml.

As signatories to the United Nations Convention of Biological Diversity, the six countries in the Coral Triangle region are committed to conducting national ecological gap analyses. Thus far, the Philippines, Malaysia, Indonesia, Timor-Leste, and the Solomon Islands have completed these analyses (White 2012). As part of the Coral Triangle Initiative, the six countries committed to the establishment of a comprehensive system of marine protected areas throughout the Coral Triangle region. To effectively integrate fisheries, biodiversity, ICM, and climate change objectives, the six countries are working to perform a region-wide marine gap analysis to inform the marine protected area network design.

The potential effects of climate and ocean change add additional spatial and temporal dimension for consideration in the gap analysis. For example, if one of the management goals was to restore and protect 20



percent of critical habitats types and their associated species in a particular Fisheries Management Unit, the EAFM team needs to consider potential shifts in the distribution of habitats over time due to sea level rise (Agardy et al. 2011). In many cases, this may require revisions of the original boundaries put in place for marine spatial planning—for example, marine protected area boundaries (Figure 4). Critical fisheries habitats are those that are essential to ecosystem productivity. Critical habitats for fisheries include, for example, wetlands, mangroves, coral reefs, lagoons, nursery and spawning grounds, and "pristine" habitat areas.

Figure 4. Illustration of the potential impact that the redistribution of habitats may have on marine management interventions, in this case the boundaries of a marine protected area for seagrass habitat. (Reproduced with permission from Agardy et al. 2011)

THRESHOLD ANALYSIS – *Note: conducting a threshold analysis is a non-essential component of the EAFM planning process. It may be beyond the capacity of many EAFM planning teams, and outside experts may need to be brought in to conduct these analyses. For most EAFM planning teams, it will be sufficient to just ensure the stakeholder group understands the concept of a threshold, the potential impacts of crossing this threshold, the beneficial role that thresholds play as a tool during the monitoring and evaluation stage of the plan.*

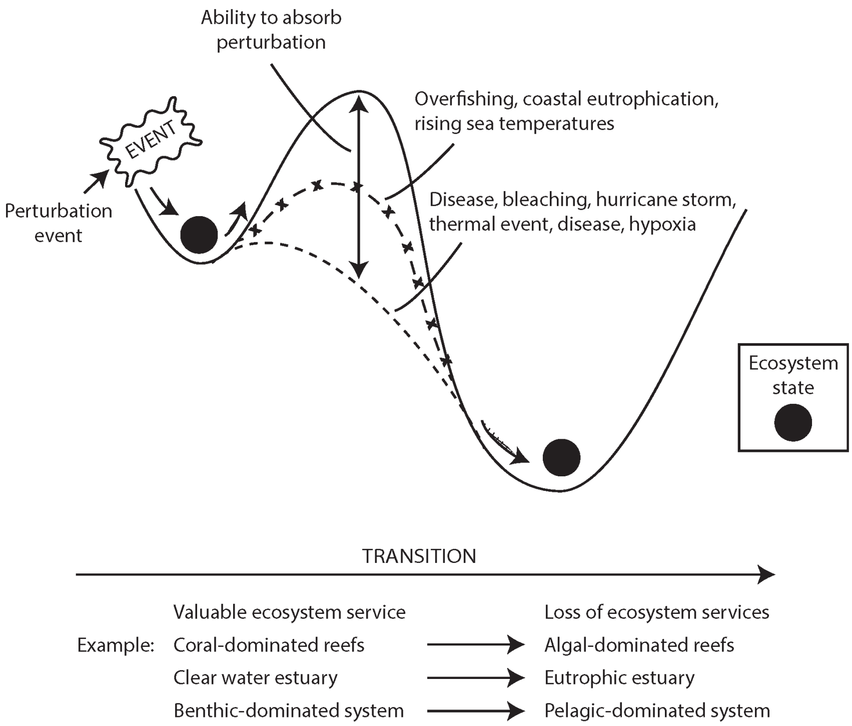


Figure 5. Systems thresholds. Natural or anthropogenic impacts can drive the system (which can be social or ecological) into a new, often undesirable and difficult to reverse state with reduced ecosystem services. The ability of the system to absorb these events (termed resilience) can depend on the additional natural or anthropogenic threats that the ecosystem is subject to, such as fishing pressure, coastal eutrophication or bleaching events. Less resilience systems can shift from a desired ecosystem state with valuable ecosystem services, towards a less desirable state where ecosystem services are lost. More resilient systems have a greater ability to absorb these events without shifting into an undesired state.

THE CONCEPTS OF THRESHOLDS, INDICATORS, AND CRITERIA IN RESOURCE MANAGEMENT

A threshold is a level beyond which a system undergoes a significant change. In the context of EAFM, the system can be social, ecological, and/or economic (Figure 5). Indicators are measures of attributes that reflect the system status or a change in condition, and finally criteria are standards or rules (whether models, tests, or measures) that govern judgments on system conditions.

To illustrate these concepts, here is an example from a recent study on multi-species coral reef fisheries in the Indian Ocean (McClanahan et al. 2011). The indicator in this case was target fish biomass (used as a proxy for fishing intensity). Different thresholds of ecosystem state exist along the continuum of fish biomass. For example, if fishing intensity causes fish biomass to fall below a particular level (the threshold), macro-algal sites become more dominant. The system then shifts into a different ecosystem state, in this case a macro-algal rather than coral-dominated state. Criteria are set and these reflect the interaction of processes and factors (social and ecological) that determine the threshold level, beyond which further change in the indicator is unacceptable (in a management context).

To extend the Indian Ocean example further, there could be a management threshold in the EAFM plan on the acceptable level of target fish biomass, beyond which a management intervention would be triggered—for example, a reduction on allowable fishing effort. Threshold levels and the criteria are can be agreed upon during the consultative planning process for EAFM (see Step 3) and once the threshold is crossed, the management actions are put into place immediately. As such, recognizing thresholds can be a powerful way with which decisions can be made over management actions/interventions.

THRESHOLD ANALYSIS – In brief, the threshold analysis includes four main assessments. First an assessment is made of vulnerability thresholds for critical system components. An assessment is then made on the consequences of crossing these thresholds and the conditions that would cause the thresholds to be exceeded. Finally, the likelihood that thresholds will be crossed is assessed.

The benefit of conducting a threshold analysis is that it provides a framework through which the potential impacts that climate and ocean change on the social-ecological system that makes up the fisheries management unit is assessed. By doing so, this can help differentiate between impacts that 1) should be considered a priority in the planning process for which management objectives are set; 2) are not a critical consideration; and 3) require further research as currently there is insufficient information to warrant including or excluding it from the planning-process management objectives.

Conducting a threshold analysis can be a complex process; refer to the State of California Central Valley Flood Management Planning Program Climate Change Threshold Analysis work plan as an example (State of California 2010).

LOCAL CLIMATE STORY – Previous activities in this step will help to assess climate and non-climate impacts on the Fisheries Management Unit. The purpose of this final step is to examine the potential impacts of climate and ocean change to the Fisheries Management Unit. Writing a "local climate story" is one way to do this. While the local climate story can be written by the EAFM team, stakeholders are central to the process and should be asked about how community and marine resources recovered after past environmental change events. Using this technique will provide a framework for incorporating scientific data, information, and local knowledge of impacts and recovery. This approach can help identify potential strengths and weakness within the ecosystem or fishery with regards to coping with future climate changes. The following describes a series of exercises that the EAFM team can do to gather information when writing a local climate story for a Fisheries Management Unit. For more information, refer to the Step 2 of the US Coral Triangle Initiative Support Program (2013) LEAP Guide.

WRITING THE LOCAL CLIMATE STORY – It is useful to understand which climate and ocean change hazards and related impacts are most important for the fishery and related ecosystems so that they can be addressed in the EAFM plan. As mentioned earlier the EAFM planning team can write the local climate story, but the information to complete it needs to be collected from stakeholders, potentially through community meetings and focus group discussions. The aim is to summarize past, present, and future climate scenarios of the fishery and habitats into a short account that describes the local situation. The following exercises can be used to gather local information:

- Compile a historical timeline – to collect information on past climate events that occurred, their frequency and impacts, and ways in which the community and resources recovered successfully or not.
- Outline a seasonal calendar – to collect information on normal and changing trends in yearly seasons and associated events such as storms and species availability.
- Conduct a community walk – this will help to talk to fishers and community members and review which areas were most impacted by which past climate events.
- Perform a strength/weakness analysis – to explore the ability of the fishery (fishers, fish, habitats) to successfully prepare for or recover from climate events. Also, it will help identify what challenges the fishery faces to cope with climate events.
- Based on the local information and known regional climate projections, undertake a discussion on which climate hazards and associated impacts are of most concern about adapting to in the near future.

STEP 2. IDENTIFY AND PRIORITIZE ISSUES AND GOALS

STEP 2.1 IDENTIFY THREATS AND ISSUES – Stakeholders undertake an initial evaluation of the threats and issues associated with the fishery, including those associated with the impacts of climate and ocean change.

STEP 2.2 PRIORITIZE THREATS AND ISSUES

STEP 2.3 DEFINE THE GOALS FOR EAFM PLAN – If issues of climate and ocean change are identified and prioritized, a goal should be included in the EAFM plan.

STEP 2.4 CONSIDER ISSUES, CONSTRAINTS AND OPPORTUNITIES TO ACHIEVING GOAL(S)

STEP 3. DEVELOP THE EAFM PLAN

STEP 3.1 DEVELOP OPERATIONAL OBJECTIVES BASED ON THE ISSUES AFFECTING THE GOALS – The stakeholder group will decide on the overarching goals and operational objectives of the EAFM plan, based on the information gathered during steps one and two. If climate and ocean change are identified as priority threats to address in the EAFM plan, then climate-change goals, objectives, indicators, and benchmarks need to be identified and added to the broader EAFM goals.

The EAFM goals identify the broadly desired results of the EAFM plan; an example EAFM goal could be to *build climate resilience in coastal fish habitats*. Operational objectives are more detailed actionable statements on how the wider goals could be achieved through specific management actions—for example, *to eliminate fishing pressure on species that are key to resilience processes, such as herbivorous fishes*. The ecological rationale for this example objective is that having a higher abundance of herbivorous fishes can help to prevent macro-algal and algal domination following a thermally-induced coral bleaching event. EAFM will also contain social goals—for example, to build climate resilience in coastal fishing communities; the objective to achieve that could be *to reduce the number of fishers targeting climate vulnerable species as their main source of income/food*.

The process of using goals and objectives to define operational objectives turns what is a high level aspiration (goal) into something that is achievable, or doable over a shorter-term through management intervention. Operational objectives are defined only for the priority issues as identified through stakeholder engagement during Step 2.2.

STEP 3.2 DEVELOP INDICATORS AND BENCHMARKS – Indicators are used to evaluate whether the management actions are achieving the specific objectives through comparison with established reference values termed benchmarks. For example, the ratio of resilience species within the total catch landed could be an indicator, with a benchmark value specifying the desired state of the indicator. To continue this illustrative example, if the management action is to eliminate fishing pressure on herbivorous fishes over a certain size, then the benchmark would be that herbivorous fishes over that size would not be present in the catch landings at

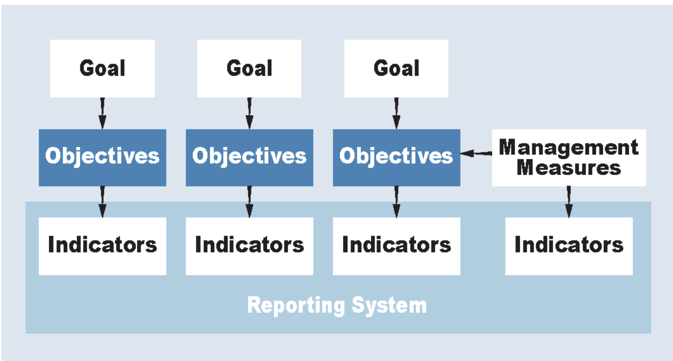


Figure 6. The EAFM plan includes goals (agreed upon during a consultative process), for which clear and precise objectives are defined. Indicators are used to evaluate whether the management actions are achieving the specific objectives, and these are reported out to inform the efficacy of the management plan.

all. Performance measures are then used to measure how well the management actions are performing, and these are simply the differences between the indicators and the benchmark values (Figure 6).

The effects of climate change and ocean change will exceed the time frame over which typical community-based management decisions are made. It is, therefore, quite likely that the impacts of climate and ocean change may not rank amongst the highest-priority issues for which local management goals are set, given the available funds and resources. As the EAFM process is adaptive, there will be repeated opportunities to revise and include climate goals as the process unfolds over time and additional information becomes more readily available. The period over which the plan is evaluated and adapted will depend on the planning process in which the EAFM plan sits, for example, the agency strategic review and planning process.

STEP 3.3 MANAGEMENT ACTIONS AND COMPLIANCE – Specific management measures and actions to address the impacts of climate and ocean change on fisheries and marine habitats should be identified, the organization and stakeholders who will finance and implement the plan.

STEP 3.4 FINANCING MECHANISMS

STEP 3.5 FINALIZE THE EAFM MANAGEMENT PLAN

DO

STEP 4. IMPLEMENT THE EAFM PLAN

Once a plan is developed, it must then be put into action. To ensure the management measures or interventions are being successfully achieved, monitoring, control, and enforcement take place. This information is used to keep the stakeholders informed as to whether the management objectives are being achieved and to reveal areas of the plan where adjustments need to be made in order to achieve goals. For example, by the implementation stage, ideally the EAFM plan should be integrated in some way with other climate-change adaptation and marine-management efforts, such as coastal and marine spatial planning. Integration of different planning efforts will prevent conflicting goals and address issues of maladaptation. Coordination opportunities are inherent to the adaptive management cycling integral to EAFM plans.

STEP 4.1 FORMALIZE, COMMUNICATE AND ENGAGE – Clear communication about the role of climate-change impacts in fisheries management is essential. Miscommunication will undermine stakeholder confidence in the EAFM team and damage their credibility in otherwise legitimate areas (Naess et al. 2006). Incorporating climate change and ocean change into fisheries management will demand the consideration of decisions on time scales that exceed the time frames over which many or most stakeholders and many of the agency officials responsible for implementing coastal and fisheries management operate. This kind of perceptual shift in time horizons will call for a populace that has an increased awareness of the likely impacts of climate and ocean change. An EAFM includes a continual process of awareness raising that needs to be expanded to include climate change and ocean change.

It is especially important to promote training and education of young people, who will form the next generation of decision makers. This could be achieved by formally including climate and ocean change into environmental subjects in national curricula at the primary, secondary, and tertiary levels. In addition, informal educational opportunities should be considered for people unable to access formal schooling and in cases where amending national curricula is a lengthy or overly politicized process.

Interactive tools are novel ways in which the potential impacts of climate change on coastal fishing communities can be explored. An example is ReefGame, which forms part of the Ecosystem Based Management Toolkit for Philippine Coastal Resource Management (Cleland et al. 2010). This board game is linked to a computer-simulation model that allows the players (fishermen and stakeholders) to link their decisions and the impact this has on associated habitats to fish landings. This has proved effective in stimulating discussion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between fishermen, local government units, and other stakeholders, such as the tourist industry and aquaculture operators. A similar, or modified, version could include climate and ocean change scenarios.

STEP 4.2 GOVERNANCE CHECK – The *Coral Triangle Regional Ecosystem Approach to Fisheries Management Guidelines* outline the necessary legal basis and policy framework for an EAFM. Climate change and ocean change specific policy will be required to support the EAFM plan in a changing climate. Examples of supporting climate and ocean change policies for an EAFM are:

- Strengthen governance for sustainable use of all coastal fish habitats by building the capacity of management agencies to understand the threats posed by climate and ocean change; empowering communities to manage fish habitats; and changing agriculture, forestry, and mining practices to prevent sedimentation, eutrophication, and other land-based sources of pollution.
- Minimize barriers to landward migration of coastal habitats during the development of strategies to assist other sectors in responding to climate change, particularly sea-level rise.
- Promote mangrove re-planting programs in suitable areas to meet the twin objectives of enhancing habitat for coastal fisheries and capturing carbon.
- Apply "primary fisheries management" to stocks of coastal fish and shellfish to maintain their potential for replenishment.
- Increase access to tuna for the food security of coastal communities and island nations where protein access is limited and expensive, where required by installing anchored fish aggregating devices (FADs) in inshore areas and reducing national allocations to industrial fleets.
- Halt or reduce exacerbating threats such as fisheries overcapacity, pollution, and poor land-use practices.

STEP 4.3 CO-MANAGEMENT FOR IMPLEMENTATION

STEP 4.4 CONFLICT MANAGEMENT – A conflict refers to a situation in which at least two parties simultaneously attempt to acquire an available set of scarce resources (Wallensteen 2007). Fisheries conflicts are common between different gears (small scale versus industrial fishers) and species that are harvested at different stages in their life cycle (e.g. sea cucumbers). Climate and ocean change are likely to exacerbate such conflict, especially in cases where our current understanding of the impacts is limited and uncertainties remain high. It is therefore important that the mechanisms outlined in the EAFM plan for management and resolving conflict are likewise adaptive to change. It is expected that competition for fisheries resources will intensify as climate- and ocean-change cause changes in abundance, composition, and distribution of species over time. Two scenarios that could create conflict area decrease in local stock abundance through redistribution to other areas, or an increase in the number of users or their consumption patterns. Areas more resilient to the impacts of climate and ocean change may experience an influx of people from less resilient or more impacted areas.

It is necessary to consider the full breadth of activities and sectors associated with fisheries and climate change. There are sectors that currently seem unconnected that could be in conflict under different climate and resource conditions. For instance, plans to install offshore wind farms (decided by the sector responsible for climate mitigation to curb greenhouse gas emission) could reduce fishing opportunities, resulting in conflict between wind farm developers and the fishers. Conflicts can change over time: fishing grounds may shift, or different gear types could be used which enable fishers to fish in and around the turbines. Proactive and anticipatory management through an EAFM will be required to deal with the dynamic nature with which conflicts may arise and change over time.

STEP 5. MONITOR, EVALUATE, AND ADAPT

STEP 5.1 MONITORING PERFORMANCE OF MANAGEMENT ACTIONS – There are two types of monitoring relevant to an EAFM: 1) measuring the performance of management measures (the focus of this section); and 2) assessing the state of the ecosystem (outlined in section 8).

The main purpose of performance indicators is to measure, monitor, and report on the progress of the EAFM objectives and indicators to measure and track progress in achieving the goals of the plan. If climate threats are identified as a priority issue in the scoping phase and during Step 1, then the plan will contain objectives and performance indicators that address these climate and / or ocean change threats. An indicator can be a quantitative or qualitative measure of the effectiveness of management actions and interventions that can be used to determine whether the objectives of the EAFM plan are being met. This is essential to documenting and communicating whether the EAFM plan is being implemented effectively and whether the desired outcomes are being achieved. An indicator can measure social, economic, or ecological performance.

Care should be taken when selecting the best suite of indicators to be used so as to effectively balance relevance and practicality. The following are some general characteristics of good indicators for an EAFM plan (see Table 3. step 10).

Readily measurable: On the time scales needed to support management, using existing instruments, monitoring programs, and available analytical tools.

Cost-effective: Monitoring resources are usually limited.

Concrete: Indicators that are directly observable and measurable (rather than those reflecting abstract properties) are desirable because they are more readily interpretable and accepted by diverse stakeholder groups.

Interpretable: Indicators should reflect properties of concern to stakeholders; their meaning should be understood by as wide a range of stakeholders as possible.

Grounded in theory: Indicators should be based on well-accepted scientific theory, rather than inadequately defined or poorly validated theoretical links.

Sensitive: Indicators should be sensitive to changes in the properties being monitored (e.g. able to robustly detect trends in the properties or impacts).

Responsive: Indicators should be able to measure the effects of management actions to provide rapid and reliable feedback on their performance and consequences.

Specific: Indicators should respond to the properties they are intended to measure rather than to other factors

The selection of performance indicators that are relevant to climate and ocean change will largely depend on the relevant goals and objectives in each individual EAFM plan and the jurisdiction of the different managers over the area. Climate and ocean change will lengthen the time scales that some indicators will need to be monitored. As our understanding of the impacts of climate and ocean change continues to advance and new tools are developed to assess these impacts, performance indicators will likely change as well. As a starting point, the following are examples of performance indicators associated with climate change goals that could be considered in an EAFM planning process.

Goal	Objective	Indicator
To increase food security	To minimize food dependency from fishery species vulnerable to climate change to more climate change "robust" species.	Ratio of climate change "robust" species to climate change vulnerable species as a percent of the total protein supply.
To build adaptive capacity of fishermen to climate change.	To increase awareness of the link between climatic events and livelihood accessibility	The number of fishermen with mobile phone subscriptions per 1000 people able to receive text messages for weather forecasts.
To build resilient marine and coastal communities	To increase reef resilience by protecting climate resistant and tolerant coral species	The abundance of massive slow-growing species which are more tolerant to thermal and physical stress.

Table 3. What makes a good monitoring performance indicator (modified from UNESCO 2011).

STEP 5.2 EVALUATE AND ADAPT THE EAFM PLAN – The continuous and iterative monitoring of management performance, followed by their evaluation and reporting, are key parts of the adaptive aspect of an EAFM. For monitoring to be most effective, operational objectives and well-thought indicators need to be identified and the EAFM plan should already include a range of ecological, socioeconomic, and governance indicators that connect their status to the operational objectives of management. Additional thought will have to be given to indicators that are sensitive to the impacts of climate and ocean change.

SECTION 6

SCALING UP

The scaling factors that are considered as a regular part of EAFM provide a good framework for dealing with the impacts of climate change considerations. For example, warming conditions causing the redistribution of target fish stocks would have to be factored into fisheries management planning, and the EAFM planning process provides an opportunity to do so. There are a number of scaling factors that are considered during the implementation of EAFM—ecological, socioeconomic, legal and jurisdictional, and temporal—each of which are relevant to dealing with the wider implications of a changing climate.

Ecological scaling includes considering a multi-species assemblage, rather than the catch of the target stock. By considering species other than the current target, information can start to be collected on potentially climate vulnerable and climate resilience species; this can, for example, help to identify future target species. Large-scale climatic processes are also considered within EAFM—for example, what effect does El Niño have on target stocks? Understanding how the fisheries management unit responds to current fluctuations in environmental conditions can give a good idea on how the unit will need to react to climate change. EAFM also factors in, for example, considering food web processes (the flow of energy through the biological system). Recognizing the connectivity between changing environmental conditions and target and non-target species will help to infer what effect longer-term climatic change may have on fisheries. These broader ecological considerations can help to broaden the geographic scope of the fisheries management unit. That is not to say that the boundaries of the unit will necessarily change; the current legal and jurisdictional governance structure that is in place may restrict an official expansion of boundaries, but EAFM provides a framework to work and co-operate over a larger scale—for example, collaborating and coordinating management activities across multiple coastal communities in an entire bay.

Socioeconomic factors are a key part of EAFM, and considering the dynamic nature of fisheries (where people will want to fish and why) over longer time frames will be important for assessing how and whether the fisheries management unit may have to respond to changing climatic conditions.

Legal, jurisdictional, and sectoral expansion and coordination across institutes will be particularly important for maximizing the efficiency of management actions, and for making sure the priorities of research institutes are more closely aligned with management information needs. Using the adaptation option framework (Section 7) can help to guide planning decisions toward management actions for near and long term gains that address the variety of drivers affecting the fisheries management unit, in addition to the impacts of climate change.

Finally, the time scale over which management decisions are considered will need to be lengthened. This will be challenging, as the most pressing issues currently facing a fisheries will be always be the management priorities. EAFM does, however, provide an excellent opportunity for a more responsive and dynamic approach to management that can flex and adapt over time. This is because planning process revolves around an adaptive resource management cycle. Adaptive resource management provides an opportunity to learn through the process of implementing the management plan. There are regular feedback mechanisms through which management objectives are assessed, revisited and revised. Should climate impacts become a more pressing priority issue to the fisheries management unit, the management strategy can be updated in EAFM.

SECTION 7

ADAPTATION OPTIONS: A PRACTICAL FRAMEWORK

The projected effects of climate and ocean change on the production of coastal fisheries in the Coral Triangle are not the only influences on the future of the fisheries and coastal resource management sectors. Population growth and urbanization, patterns of economic development, status of fisheries resources in other oceans, governance and political stability, markets and trade, fuel costs, technological innovation, and foreign aid can all be expected to influence fisheries and aquaculture in the region (Gillett and Cartwright 2010; Hall 2011). Population growth and urbanization are expected to be particularly significant in Papua New Guinea and the Solomon Islands (Bell et al. 2011). Climate adaptation plans should be developed to identify management actions that will reduce vulnerability to climate-related threats by addressing the risks from coastal and climate hazards and complementing environmental, economic, and community goals. A framework is needed for planning adaptations that address the myriad of other drivers in the near term, and climate and ocean change in the long term, which can help identify and avoid potential planning adaptations that have near-term gains but long-term losses (maladaptive actions) (Grafton 2010). The best investments are those that deliver both short-term and long-term benefits ("win-win" adaptations) (Figure 7). Adapting to climate and ocean change will inherently involve some "lose-win" adaptations—where the economic and social costs exceed the benefits in the near term, but where investments position coastal communities to receive net benefits in the longer term under a changing climate.

PROPOSED ADAPTATIONS FOR FOOD SECURITY AND LIVELIHOODS – Adaptations proposed by Bell et al. (2011) to reduce the risks posed by climate and ocean change to the benefits derived from coastal fisheries in Coral Triangle countries, and to capitalize on the opportunities, are given below. The adaptations center on minimizing the size of the widening gap between the fish required for food security and the fish and shellfish available from coral reefs and other coastal habitats (mangroves, seagrasses, and intertidal flats) through:

1. appropriate management of coastal fish habitats and stocks;
2. increasing local access to tuna; and
3. boosting freshwater pond aquaculture.

MANAGE AND RESTORE VEGETATION IN CATCHMENTS – Increasing the vegetation in catchments will help reduce the transfer of sediments and nutrients to rivers and coasts after heavy rain and help prevent damage to the coral reefs, mangroves, and seagrasses supporting coastal fisheries (win-win).

FOSTER THE CARE OF COASTAL FISH HABITATS – Preventing pollution and managing waste in coastal areas to maintain water quality, and eliminating damage to coral reefs, mangroves, and seagrasses (e.g. by destructive fishing methods, gathering building materials, and poorly-designed tourist and commercial activities), will help sustain resilience of coastal fish habitats to climate change (win-win).

PROVIDE FOR LANDWARD MIGRATION OF COASTAL FISH HABITATS – Prohibiting construction of buildings on low-lying land adjacent to mangroves, seagrasses, and intertidal flats, and installing wide culverts beneath existing roads, will allow low-lying areas to become fish habitats as sea levels rise (lose-win).

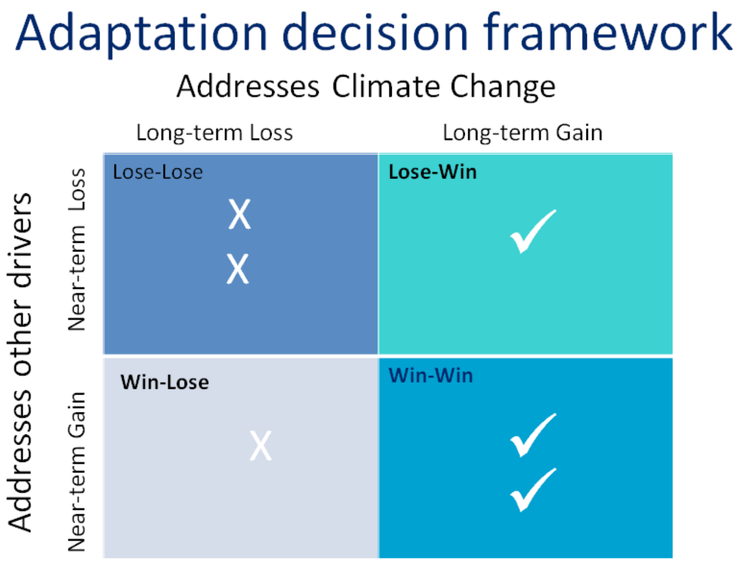

Figure 7. An adaptation decision framework for categorizing adaptation options according to whether they result in planning actions that deliver near-term or long-term loss or gains. Options for addressing other drivers are assessed alongside options for climate- and ocean-change planning actions. This type of framework can help to address win-win adaptations i.e. actions that deliver near- and long-term gains for climate and acidification threats in addition to the other threats facing the coastal fisheries.

SUSTAIN PRODUCTION OF BOTTOM-DWELLING FISH – Maintaining the replenishment potential of stocks through primary fisheries management (Cochrane et al. 2010) will help reduce the gap between coastal fisheries production and the fish needed by rapidly growing populations (lose-win).

DIVERSIFY CATCHES OF BOTTOM-DWELLING FISH – Taking catches representative of the changes in abundance of the fish that result from climate change will help optimize the potential production from coastal fisheries (win-win).

INCREASE ACCESS TO TUNA FOR FOOD SECURITY – Installing anchored fish aggregating devices (FADs) to attract tuna close to the coast will provide subsistence and small-scale commercial fishers with better access to fish as human populations increase and coastal bottom-dwelling fish decline (win-win).

DEVELOP COASTAL FISHERIES FOR SMALL PELAGIC SPECIES – Increasing the catch of mackerel, anchovies, pilchards, sardines, scads, and fusiliers will improve access to fish for food security and livelihoods (win-win).

EXPAND FRESHWATER POND AQUACULTURE – Identifying the hatchery systems and networks that allow high-quality juvenile fish to be distributed to both small-scale and large-scale farmers, and securing the supplies of cost-effective feeds required for semi-intensive and intensive farming systems, will help increase access to fish for coastal communities with adequate freshwater supplies (win-win).

IMPROVE POST-HARVEST METHODS – Training communities, particularly women, in appropriate ways to improve traditional smoking, salting, and drying methods will extend the shelf-life of fish when good catches are made (win-win).

REBUILD POPULATIONS OF SEA CUCUMBERS AND TROCHUS – Restoring the densities of these valuable species to levels above the thresholds required for regular replenishment will result in some loss of income in the short term but set the stage for greater benefits in the future (lose-win).

DEVELOP CORAL REEF ECOTOURISM VENTURES – Reducing the pressure on fisheries resources by providing viable alternative sources of income for local communities in the tourism sector is expected to make fisheries for bottom-dwelling fish and shellfish less vulnerable to climate change (win-win).

DIVERSIFY PRODUCTION OF COASTAL AQUACULTURE COMMODITIES – Assessing the potential to grow "new" commodities favored by projected climate and ocean change may create new livelihoods, provided aquaculture development remains within the carrying capacity of coastal waters (win-win).

MODIFY LOCATIONS AND INFRASTRUCTURE FOR COASTAL AQUACULTURE – Timely alterations to the design and position of facilities can help reduce the expected negative effects of sea-level rise, ocean acidification, and increased seawater temperatures on coastal aquaculture activities (lose-win).

SECTION 8

MONITORING

Monitoring is a key activity in EAFM. There are two points at which monitoring plays a role in the EAFM plan: 1) when measuring the performance of management actions (see section 7 step 10) and 2) assessing the state of the ecosystem.

The impacts of climate and ocean change on socio-ecological systems will be complex and potentially synergistic. Monitoring is necessary to detect change in the state of the socio-ecological system in the Fisheries Management Unit. This means that both biological and social change must be monitored, as well as any changes in governance (Agardy et al. 2011). Monitoring for climate and ocean change differs from typical socio-ecological monitoring required for an EAFM due to the extended spatial and temporal scales and the uncertainty associated with the impacts of these changes. This calls for the long-term monitoring of standardized socio-ecological indicators that can be applied across the region. Region-wide application is especially important, as the impacts of climate change and ocean acidification may not always be readily apparent at local-level monitoring.

Suitable indicators are required, which can be used as a baseline to understand changing climate conditions and the impacts of these changes. Not all aspects of the biophysical and social system can be measured, therefore knowledge-based extrapolation should be used to identify the most suitable and relevant indicators. As mentioned in section 7 (step 10), good indicators for monitoring are those which are based on well-supported and accepted science. The monitoring of some indicators will be best applied as a regional- or national-level activity, particularly for some of the technically demanding components (see Section 9)—for example, the monitoring of physical indicators like sea-surface temperature, solar radiation, surface winds, currents, and pH. However, the monitoring of carefully selected indicators for climate impacts that are appropriate to assess at the scale of the fisheries management unit can help to reduce the uncertainty surrounding what affects these impacts may have. Good candidate biological indicators will be those that are likely to be sensitive and responsive to climate impacts—for example, species that provide structural integrity of habitat, like corals or seagrasses, or species that play key ecological roles, like phytoplankton that form the basis of marine food webs (Hobday et al. 2006). Based on an expert workshop review process, Wongbusarakum and Loper (2011) provide guidance on appropriate social indicators to monitor the sensitivity and vulnerability of fishing communities to climate change. These include assessing adaptive capacity (the potential of a community to adjust to impacts of a changing climate) by using indicators like, for example, the current livelihood and income diversity of households through household surveys. Refer to the SocMon and SEM-Pasifika report for more details on how this type of community information can be gathered and used (Wongbusarakum and Loper 2011).

Our understanding of climate and ocean change will continue to develop, so additional indicators may become apparent over time. The challenge, then, is to implement a standardized, yet sufficiently flexible, monitoring approach region-wide to allow for modification when new information demands revisions of the indicators and standardized approaches.

Equally challenging will be the allocation of monitoring resources in the most effective manner. A lack of monitoring for impacts of climate and ocean change will come at the cost of the information required to assess changing environmental conditions and the ability to update and or validate management actions. Ineffective monitoring will also incur this cost, in addition to wasting the meager resources typically available for most

monitoring efforts. A practical and prudent attitude should be taken when considering monitoring to support an EAFM; a long-term commitment to the sustained monitoring is required, and the expectations and design of the monitoring program should be carefully considered and regularly evaluated over time (UNESCO 2011).

When implementing a monitoring system that can detect climate- and ocean-change impacts, one of the most important considerations is identifying the appropriate approach to deliver the desired outcomes (EAFM in a changing climate), given the resources available. The resources that are available need to be related to the potential benefits from any investment made in monitoring. If resources are meager, then data-intensive monitoring cannot be implemented for more advanced scientific analysis. This will lead to a high amount of uncertainty surrounding the management interventions. Assessing the impacts of climate and ocean change will add an additional element of uncertainty surrounding management interventions and how the ecosystem may respond. The best way to cope with these uncertainties is to adopt the precautionary approach when considering management interventions.

SECTION 9

WHAT CAN BE DONE AT NATIONAL AND REGIONAL LEVELS TO SUPPORT COMMUNITY-LED CLIMATE-CHANGE ADAPTATION WITHIN AN EAFM?

This guidance is specific to national and regional activities that will strengthen links and facilitate and support community-based engagement in incorporating climate-change adaptation within an EAFM.

9.1 NATIONAL LEVEL ACTIVITIES

GETTING STARTED – Any country wanting to be able respond to climate change and ocean change will require a level understanding of the likely impacts, issues, key people/organizations, and actions required. This can be achieved by:

- Conducting national and sub-national climate change vulnerability assessments for fisheries and associated socio-ecological systems and committing to reviewing these assessments at regular intervals—for example, every two to five years.
- Conducting community-level gap analyses on the capacity to deal with the impacts of climate and ocean change on fisheries within the Fisheries Management Unit. Use these gap analyses to identify specific management actions offering the highest potential return and to identify priority geographic areas or communities of the fisheries sector that are most vulnerable to climate and ocean change.
- Analyzing current legislation to identify gaps and/or barriers which may hinder or prevent the effective implementation of an EAFM in a changing climate.

SUPPORTIVE AND CO-COORDINATING ACTIVITIES – For communities within an Fisheries Management Unit, effectively incorporating adaptation to climate and ocean change into an EAFM will require the support and services of their national government. There are a number of supportive services and coordinating structures which if implemented nationally could significantly inspire, enable, or enhance community-led responses:

- Devise policy statements and/or legislative support that will empower and facilitate the local implementation of fisheries-management decisions in the context of climate change.
- Encourage and enable provincial, district, and municipality-led climate change vulnerability assessments and commit to providing the essential climate-related information and support to assist these efforts.

- Establish a single authoritative source for collating and managing climate data and associated climate-change information and projections. This source should be responsible for the active and timely reporting of climate data in forms that can be used to support fisheries management decisions—for example, layman summaries and user-friendly graphics. Copies of all outputs should be kept at the village level and preferably be in local language where possible.
- Have national-level institutional support to coordinate education, outreach, and awareness raising via organizations like the CTI Mayors Round Table, Timor-Leste cooperative, Indonesian National Coastal Mayor's Association.
- Establish legally mandated national and local committees tasked with facilitating inter-ministerial coordination and cooperation.
- Dedicate a task force to support local knowledge requirements and the capacity to make climate -change-related management decisions and partner task forces in each region.
- Establish what national financial and infrastructure resources will be available to support provincial, district, and community-based climate-change-related activities, and work with appropriate local representatives to enable access to multi-level climate changing funding opportunities. Consider devising incentive-based policies to manage access to such funds with clear counterparts from local government and communities.

FURTHER KNOWLEDGE AND UNDERSTANDING – A critical step towards being able to incorporate considerations of climate and ocean change into an EAFM is an acceptance that the climate is changing and that marine ecosystems, resources, fisheries, and coastal communities dependent upon fisheries will be impacted. This can be achieved by a societal-level increase in awareness of the likely impacts of climate and ocean change, from the general public to national decision makers. The following actions may help to achieve this:

- Promote government-level training and education in the new issues related to climate and ocean change, with a view to embedding the concept and impacts of climate change within national decision-making and research agendas. One way to achieve this could be through establishing a regular reporting process that disseminates each of the updated IPCC Assessment reports, provides derived projections of climate changes and impacts at regional, national, and subnational scales, and disseminates these information products in a user-friendly manner capable of informing the general public, including mechanisms for community members to ask specific questions related to local impacts.
- Promote training and education in young people. This could be achieved by formally including climate and ocean change into environmental subjects in the national curricula at primary, secondary, and tertiary school levels. Also consider informal educational opportunities for people unable to access/avail of formal schooling and if amending national curricula is a lengthy or overly politicized process.
- Develop innovative, interaction tools to promote learning. Each of the Coral Triangle countries except Timor-Leste thus far have embraced and are testing the One Laptop Per Child Program (http://laptop.org), an initiative to distribute affordable laptop computers as learning tools for young students. This is a freely available platform on which climate- and ocean-change simulation games could be developed and run to explore different climate scenarios and adaptation options. There is also a call to develop a state-of-the-art interactive computer games that will be freely accessible via the internet.
- Mainstream climate and ocean change as a topic relevant to fisheries management through the regular reporting processes on climate impacts. This could be achieved by using the reporting processes already in place for the Coral Triangle—for example, in the State of the Coast reports or the State of the Coral Triangle Reports and the Regional State of the Coral Triangle Report.

9.2 REGIONAL LEVEL ACTIVITIES

Coordination across the Coral Triangle region is equally essential to enable national- and local-level actions and render them as effective as possible. There are a number of ways that regional developments will facilitate national and subnational local actions as follows:

- Build and support the structured sharing of knowledge through learning networks. People tend to learn effectively through the experience of others, and learning networks are an effective way to promote the understanding of key issues by decision makers at all levels, from regional, national, to local staff. Examples are the Locally-Managed Marine Area (LMMA) network, which shares community-based experiences of marine protected areas, and the Pacific Islands Marine Protected Area Community (PIMPAC), which is a marine protected area support network that trains trainers in climate-change adaptation.
- Champion national requirements for scientific information, fisheries management, and emission policies within appropriate regional and global forums—for example, the Coral Triangle Initiative, the Association of Southeast Asian Nations (ASEAN), the United Nations Food and Agricultural Organization (FAO)-Asia Pacific.
- Identify and build links with initiatives with overlapping agendas in relation to the impacts of climate change and ocean change on fisheries. Examples include the Pacific Island Framework for Action on Climate Change, Regional Strategy for Food Security, Asian Development Bank and Secretariat of the Pacific Community research on Food Security, Asian Development Bank Knowledge management theme for Fisheries and Economic Analysis.
- Use existing technical working groups—for example, the National Coordinating Committees (NCC) of the CTI—to integrate and strengthen regional and national plans of action for fisheries.
- Identify opportunities and barriers for the trans-boundary management of fisheries in a changing climate. Address trans-boundary difficulties so as to avoid inertia in relation to managing fisheries in the face of climate change and ocean change.
- Establish a regional scientific advisory group which can provide independent expertise in an EAFM, and climate-change and ocean-change science. The Independent Science and Partnership Council to the Consultative Group on International Agriculture Research is an example model.
- Develop regional standards and strategies to inform and direct national monitoring efforts of socio-ecological systems to enhance the implementation of an EAFM in a changing climate. Build capacity, via regional cooperative programs, to enable effective monitoring. This can include data-management processes, which can link national to regional data collection readily.

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APPENDIX A

LIST OF WORKSHOP PARTICIPANTS

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APPENDIX B

DETERMINING WHETHER THE EAFM TEAM IS READY TO INSTIGATE AN EAFM-CCOA PLAN

Taken from the VA LEAP. Activity to determine if the EAFM team are ready to carry out an EAFM-CCOA plan that considers the impacts of climate and ocean change.

	Organization Statement	**YES/ NO**	**Example Answer**
1	We have clearly defined the results we would like to achieve from developing a plan for climate adaptation at this time.	YES	What is your reason? We are noticing changes that might be related to climate change and want to understand how our fisheries and habitats might be impacted and what we can do.
2	People in our community really want to develop a plan.	YES	There have been several meetings with the community leadership and key representatives and they are supportive of having more discussions to better prepare for CC and manage resources.
3	We have identified a strong team of local leaders and experts that have agreed to develop the plan. Who are they and what skills to they bring? (For example, representatives from the following sectors: traditional or municipal councils, fisheries.)	YES	Team members: Traditional leader – lead community in discussions and decisions. Representative of Women's Group – will help organize meetings and women's voice. Two members of our fishing organization – will provide support in organizing the fishers meetings, keeping records, and providing outreach. Representative from local government.
4	We have identified a neutral person who will lead the plan process.	YES	Who? Representative from academia, NGO and/or government – will facilitate process.
5	We have the authority to carry out a plan process.	YES	Yes, we have both traditional leaders and government leaders engaged and supporting this effort.

	Organization Statement	YES/ NO	Example Answer
6	We have a clear plan for who will use the plan and how it will be used.	YES	When? This will guide the fisher community based organization activities as well as local government planning agencies that will support this effort.
7	We have a target date for finishing the plan.	YES	November 2012.
8	We know how the plan will be approved and who has authority to approve it.	YES	How? Members of the planning team will sign off after community meetings to endorse the proposed activities.
9	We know how the plan will be integrated into existing community plans and projects.	YES	The existing plan(s) are: Management plan for local marine managed area. Local government hazard management plans. Mangrove conservation project.
10	We have collected existing information about the area (e.g. management plans, maps, historical photos, social or biological studies, information on climate).	YES	This includes: Basic studies done by the community college on fisheries species and coral reef species. Fishing areas have also been mapped.
11	We have collected information about national and regional climate change and we know how to use it.	YES	We have the "Adapting to a Changing Climate outreach tool and Regional Climate Information Brief for the Coral Triangle."
12	Our team has sufficient time and financial resources to complete our planning process.	YES	List financial sources: There is sufficient time in the community if the process is carried out on weekends. We do not have many financial resources but have support from a local community based organization. Are funds available for a facilitator?

CORAL TRIANGLE INITIATIVE

ON CORAL REEFS, FISHERIES AND FOOD SECURITY